SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Proceedings of the REAPS Technical Symposium

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NAVAL SURFACE WARFARE CENTER

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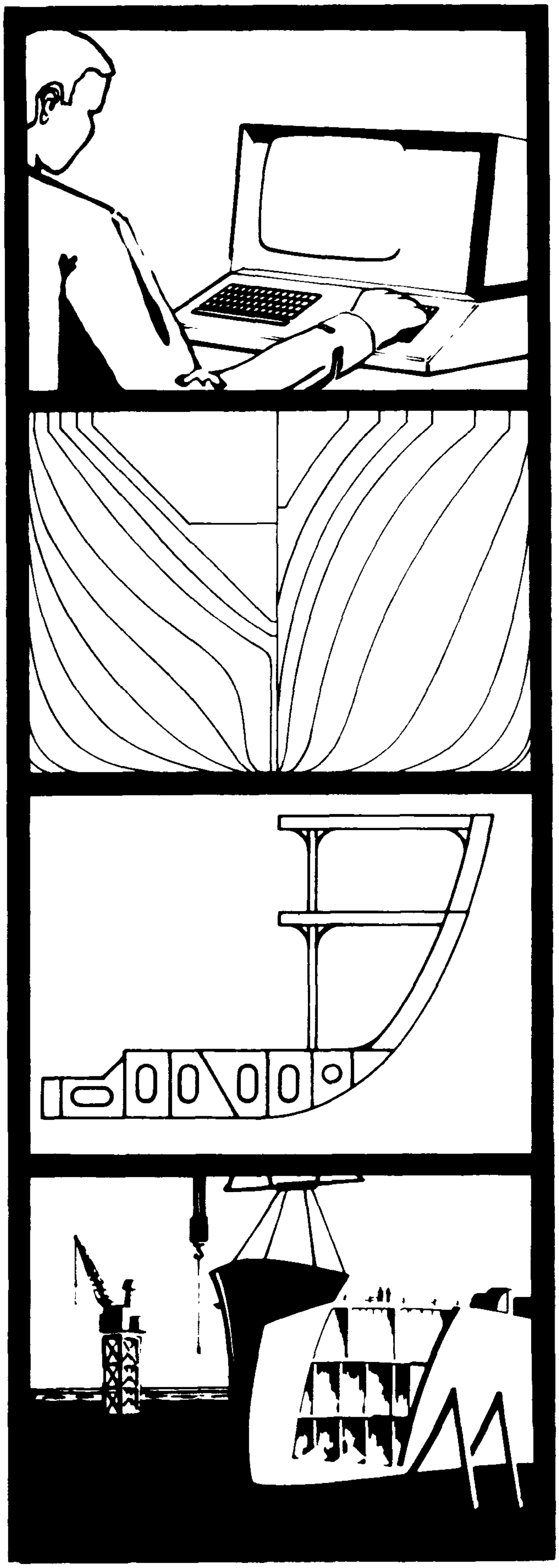

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FOR
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IN
S HIPBUILDING

Proceedings of the REAPS Technical Symposium

October 14-16, 1980

Philadelphia, Pennsylvania

Proceedings of the REAPS Technical Symposium

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San Diego, California

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PREFACE

The REAPS Program is a U.S. shipbuilding industry/Maritime Administration cooperative effort whose goal is the improvement of shipbuilding productivity through the application of computer aids and production technology.

The Seventh Annual REAPS Technical Symposium, held October 14-16, 1980 in Philadelphia, Pennsylvania, represents one element of the REAPS Program which is designed to provide industry with the opportunity to review new developments in shipyard technology.

The Symposium this year highlighted all aspects of the National Shipbuilding Research Program (NSRP)* in that presentations were made by all the panel chairmen of the SNAME Ship Production Committee.

Appreciation is expressed to the management of Sun Shipbuilding and Dry Dock Co. for allowing symposium registrants to tour their facilities. We are particularly indebted to all the people at Sun who volunteered their time to make these tours so interesting.

The 1980 REAPS Technical Symposium Proceedings contain most of the papers presented at the meeting. The agenda in Appendix A indicates topics and speakers; Appendix B is a list of symposium attendees. All current SPC-SNAME chairmen are identified in Appendix C.

* The NSRP is a cooperative effort between the Maritime Administration's Office of Advanced Ship Development and the U.S. Shipbuilding Industry.

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WELCOME

Spencer L. French
Vice President Program Support
Sun Ship Inc
Chester, Pennsylvania

Mr. French currently is responsible for engineering quality assurance, contract administration, program support, and materials management.

He holds a degree in engineering from the Rensselaer Polytechnic Institute, and had been a Naval officer from 1969 to 1973. His previous experience includes a variety of positions leading to manager, major program manager and director of program management.

I'd like to wish everyone a good morning and extend to all of you a personal welcome to the Philadelphia area. This is, of course, the city about which it has been said, with a bit of liberty, "on the whole I'd rather be in Camden." Well, first and foremost, there are no World Series teams in Camden this fall. It really doesn't take long to convert us frustrated Red Sox fans. Secondly, the square mile surrounding this hotel, as many of you know, a unique historical district certainly unexcelled by anything else in this country. I'll stop right here with the Chamber of Commerce speech - I'm sure you don't need that!

I'm also sure there's no need to wax philosophical - to take on the unnecessary task of convincing everyone here of the necessity for personal dedication to the improvements in productivity in the shipbuilding industry. Productivity is a national issue today and has suddenly caught the eye of the news media as well - Business Week, Newsweek, Time, and NBC to name a few have reported extensively on the subject.

As I read the program, I thought it encouraging for all of us that the group is so widespread in its representation. We have people here from Maine to Washington, Michigan to Louisiana and in between. Some of us represent blue, some white collar backgrounds. Some are from large shipyards and some from small, in urban and rural areas. Some are from organizations who exist solely in support of shipyards. Some are from organizations who today are here to deal within the shipbuilding environment, and tomorrow will deal with others. Industry, consultants, and academia are represented.

The diversity of this group is one of its greatest potential assets, because that diversity offers us the opportunity to present and hear ideas of a wider spectrum. This industry cannot today afford to dismiss any fellow with a 'he doesn't really know my situation" attitude. We must listen carefully to what the fellow says and draw out all the bits and pieces he might be able to contribute to our process. It appears we are beginning to do this better. Another attitude that must be put aside says "don't compare me to the Japanese, or the Koreans, or the people in Washington, Maine or Louisiana - I'm constrained by different forces.' As I'm sure most here feel, that overworked argument is getting particularly tiresome. We can complain about imagined handicaps, or we can be proactively working through the problems we face. It's how we utilize this diversity that will be much more telling and ultimately profitable. What is not done will be dangerous.

Productivity is a function of, to vary degrees, all part of the shipbuilding process. Therefore, the entire process demands scrutiny. For example, do we contract in a fashion that minimizes costs, schedules and administration without sacrificing quality, or, do our contracts become management problems themselves? Do we always seek to engineer in an improved, more productive fashion, or do we engineer "the way we've always done it"? Does material definition and procurement leading towards standardization, or towards "give me my old favorite and, by the way, change the trim and the color and the size"? Finally, is planning thought of in terms of "let's do what is logical, coordinated, and integrated' or in terms of 'I'll do what fits my style today." This choir knows the bottom line of this sermon - improvements in these areas are 'flow-down" improvements which lead to many opportunities (both technical and administrative) for improvements where the largest gains in productivity are possible - on the waterfront.

The presentations to be made during the next three days are the results of the efforts of many of you to deal specifically with some of those general issues.

One last point: as we've all experienced, the best way is usually the simplest way. Complex and highly sophisticated systems are exciting to ponder, interesting to develop, but costly to implement. Disillusionment comes fast. Return information becomes at best confusing and questionable. To borrow from a famous architect, "less is more." Our interests are served best by simplifying the way we get to the end. Let's avoid imposing defensible, logical but nonetheless additional layers of complication on the process.

I think we should commend ahead of time the efforts of all involved in preparing for this symposium. The sponsors of this program, and especially the Maritime Administration, are to also be commended for their involvement.

Sun is pleased to open its gates for tours of our facility this Thursday afternoon, and we extend an invitation to everyone to visit us.

My best wishes for a fruitful and productive symposium.

I am Chairman of the SPC. We and REAPS thought it would be educational to this symposium to share an overview of our research projects.

The SPC started with just shipyards. However we soon recognized the need to add others: USCG - USN - ABS, along with our sponsor, MarAd. We recently added design agents to our membership.

You will be hearing from our Program Managers on their projects shortly. We have many cost saving projects. They need to be implemented. We are also sponsoring a one-week class at Ann Arbor Michigan to teach shipbuilding the Japanese Way to Shipbuilders.

We are pleased to see many Navy representatives here as well as MarAd. Cooperation between commercial and Navy ships material and equipment needs can make standards work and save dollars for both. Our SPC interfaces with the Navy Manufacturing Technology group so we share information and do not duplicate programs. We try to spend taxpayer's money wisely for they are us.

SP-1 - SHIPYARD FACILITIES AND ENVIRONMENTAL EFFECTS

Richard A. Price
Program Manager
Maritime Administration Research and Development
Avondale Shipyards Inc
New Orleans, Louisiana

Mr. Price has a degree in industrial engineering from Tacoma Tech, and holds an associate degree in civil engineering from the University of Wisconsin. He has also attended Tulane University, Louisiana University, and the University of Alabama.

Prior to his present position, Mr. Price served as senior industrial engineer, ground support equipment for the Boeing Company Aerospace Division.

Mr. Pride is registered in the Smithsonian Institution and Library of Congress for outstanding achievements in the Apollo space program.

Facilities

The Ship Production Committee of the Society of Naval Architects and Marine Engineers re-activated Panel SP-1 Facilities July 20, 1978.

Avondale Shipyards, Inc. accepted the chairmanship and agreed to be the primary sponsor. Presently we have 21 active members from 17 shipyards plus MarAd representation.

During the July, 1978, meeting of Panel SP-1 (Facilities) it was suggested that the panel develop a consensus specification for long range facility plans. The purpose of the consensus specificatian is to provide a standard format and criteria for the development of facility plans. This would be a tool for use by MarAd and a specific shipyard in conjunction with the proposed facility modernization planning program.

During the development of the consensus specification, we experienced sematical problems. Avondale Shipyards, Inc. requested Mr. Richard Muther, President of Richard Muther and Associates, Inc., to speak at our November meeting. Mr. Muther is an expert in the field of Long Range Planning of Industrial Facilities.

On November 9, 1978, Mr. Richard Muther addressed the panel. His primary objective was definition which would do away with the sematical problems.

Mr. Richard Muther's presentation was successful and achieved the ojectives. At the conclusion of the one-day presentation, it was suggested that the panel request MarAd to fund a five-day Long Range Planning of Industrial Facilities Working Conference.

Mr. Garvey of MarAd accepted the proposal and funded the conference. The five-day working conference was held January 29, 1979, through February 2, 1979, in Atlanta, Georgia. Twenty-two (22) representatives from twelve (12) major shipyards attended the five-day conference and currently have a common approach for the development of long range plans.

The second phase of this effort was to prepare proposals, on a voluntary basis, for one or more shipyards to develop a long range plan for their respective yard, utilizing the trained personnel and the consensus specification as a guide.

The detailed proposals were submitted directly to the Assistant Administrator for Commercial Development.

Panel SP-1 (Facilities) currently has a three phase objective emphasing improved productivity.

Phase I - Enhance the Shipbuilding Industries Long Range Facilities Planning Efforts

Phase II - Determine a Feasible Method of Instituting a Cooperative High Risk Facilities Program

Phase III - Determine a Feasible Method of Instituting a Cooperative Facilities Modernization Program

Our efforts are directed toward achieving this three-phase objective, placing emphasis on cost effective producibility. The fiveday Long Range Planning of Industrial Facilities 'work Conference and the Development of the Shipbuilding Consensus Specification for Long Range Facility Plans are basic steps toward enhancing the shipbuilding industry's planning efforts.

'The support of the shipbuilding industry's senior management to consider developing such plans in cooperation with the Maritime Administration is essential for better understanding of the long range economic impact of promoting more productive shipbuilding facilities.

Five shipyards have developed proposals for the development of Long Range Facilities Plans have submitted their proposals to MarAd for funding.

Four yards are presently proceeding to develop their Long Range Plans. Avondale's original proposal, which was submitted on Way **23,** 1979, was rescoped and resubmitted on June 27, 1979. The reason for resubmittal was based on the rough appraisal of Avondale Shipyards, Inc.'s operations after studying the MEL Technology Survey; the Levingston/IHI Technology Transfer; Todd Shipyards' Outfit Planning Document and the Shipbuilding Industry's Consesus Specification for a Long Range Facility Plan. Our study has indicated that, in order to develop a Long Range Facilities Plan, we have to take advantage of all the technological data, which has been developed under the MarAd Research Program, because this would have a direct effect upon the Long Range Facilities Plan.

On December 28, 1979, we submitted an additional proposal to MarAd for implementation of Accuracy Control, Production Planning, Computer Application and Design Engineering for Zone Outfitting with Procurement Specifications.

Recently, we have made schedule adjustments predicated on implemantation and application of these four (4) key management mechanisms. The APL-contract will be used as a basis for measurement of improvement in our productivity and cost effectiveness. We anticipate an approximate three-month flow-time reduction from laying the keel to delivery date.

We understand from Mr. Garvey that this project will be funded by cooperative agreement rather than the standard process. We are looking forward to this method of funding which we believe will enhance the program.

Mr. Starkenburg of Avondale was invited to make the Implementation of IHI Technology presentation which is scheduled at 10:30 am on Thursday, October 16.

PROJECT STATUS

LONG RANGE FACILITIES PLANS

Shipyard'	Mo/Yr. Completion	Percent Complete
Peterson Builders, Inc.	April, 1981	25%
NASSCO	April, 1981	50%
Todd, LA	April, 1981	25%
Avondale Shipyards, Inc.	April, 1981	75%
Ingalls Shipbuilding	Not Committed	

Pipe Shop

Approximately five years ago Avondale started a feasibility study of a semi-automatic pipe handlign system and fabrication facility due to the high cost of ship piping systems. This project, it turns out, will be a major management improvement as well as a cost improvement package.

In developing this study we determined that a major change must be made in our method of designing piping as well as in our shop management program.

During the development of the shop management program, which is required to fully implement the Pipe Shop project, our Data Processing Department investigated various programs that could be utilized without major development cost. The COPICS program appeared to solve this problem satisfactorily, but in addition, it can provide scheduling systems which can include: business planning, production planning, etc. Mr. Arnold of Avondale has been requested to speak in detail on this subject at 8:30 am on October 16.

The study revealed that through automation a percentage of the required manhours can be reduced in the following functions: handling, 68%; fitting, 55%; welding, 35%; cleaning, 79%; and coating, 86%. These percentages are based on LASH vessel construction since all basic data is applicable to this series of ships. An overall percentage reduction in fabrication manhours equates to approximately 39.8% per shipset. (Note 30,000 manhours/146,00 dwt tanker.)

We expect to operate the Pipe Shop with the software during the fourth quarter of 1980. We will offer a facility demonstration to the Ship Production Committee during the first quarter of 1981.

Major Productivity Studies In Progress Currently

MarAd has authorized Avondale to conduct a study concerning the economics of the installation of beam lines in shipyards. The beam line, for your information, would be capable of deflanging structurals, cutting all shapes, angles, beams and channels.

The facility would be capable of processing 35,000 stock pieces per year on a two-shift basis for structurals and it would include marking with an accuracy of l/25 of an inch per piece in one hundred feet.

Preliminary return on investment of this facility is extremely high; it appears that an 80% reduction in manhours can be obtained with this system. Test cases that have been run on small units indicate that these results can be obtained.

Another MarAd project we are studying is a semi-automatic method to assist in the prefabrication, fabrication and assembly of webs, beams, floors, etc. The system provides a method which will reduce the labor, material handling, welding and space required for storage as well as manufacturing. The work within each functional area will he performed by use of adjustable jigging, welding gantries and other mechanical methods. Substantial emphasis will be directed toward automatic welding. Preliminary tests indicate a 43% reduction in manhours with this system.

Environmental

During 1979; we recommended that Panels SP-1 and SP-3 (Shipyard Environmental Effects) be combined into one panel. The logic being that the functional responsibility generally falls under the facilities department. We thought the combined panel would consolidate our industry's efforts regarding industry consensus Input during the comment period of proposed federal regulation.

We coordinate our efforts with the Shipbuilders Council of America Environmental Committee when dealing with governmental agencies such as the Environmental Protection Agency, the Department of Labor (OSHA), the U. S. Coast Guard, and the Department of the Navy. The shipyards, on an individual basis, have to address their respective state and local regulatory agencies to meet the intent of their regulations.

During the proposal period, part of our commitment is to ensure that the regulations are feasible regarding compliance as well as cost effectiveness. We have submitted comments to regulatory bodies as well as conducted independent studies to establish guidelines for use in the development of cost effective regulations.

We have focused on such issues as: (1) Draft Development Document for the Shipbuilding and Repair Industry Drydock Points Source Category; (2) methods of receiving sewage from vessels using drydock facilities; (3) programs for complying with National Pollutant Discharge Elimination Standard Permit requirements; (4) methods of handling hazardous waste; (5) PCB spill prevention plans; (6) civil penalties for violation of Federal Water Pollution Control Act (FWPCA); (7) certificates for financial responsibility; and (8) the OSHA Blasting Standard Development Document.

Typical equipment installed by some shipyards to control the various forms of pollution include oil containment booms, oily waste collection equipment, closed-cycle blasting equipment, water blasting equipment, special air filters, and more efficient combustion control equipment.

During the recent past the shipbuilding and repair industry through Panel SP-1 (SNAME) and the Environmental Committe of SCA have focused our attention on hydrocarbon emissions.

Several approaches have been considered: changing the solvent, inhibiting the photochemicalrectivity (Rule 66 Calif.), developing high solid coatings, developing water base coatings, utilizing carbon absorption and/or inceneration.

Carbon absorption or inceneration can provide 90% emission control, however, the cost impact is prohibitive. In most cases, this type of emission control could cost as much as the paint building.

For example, Peterson Builders is presently erecting a blast and paint building. This facility will cost approximately $650,000. If Peterson Builders has to provide 90% hydrocarbon emission control, this facility would cost in excess of $1,650,000. Presently Peterson Builders is working with their local regulatory agency to determine a cost effective approach. Our panel has responded to their request regarding "state of the art" controls within our industry.

During the past 3 to 5 years most **mil.** spec. and commercial paints comply with Rule 66. It must be noted that the shipbuilding and repair industry uses the paint specified by the owners in most cases.

Panel 023 of SNAME Ship Production Committee has accomplished substantial gains in the use of high solid low solvent coating. This industry effort is over and above Rule 66 compliance. Research and development of effective water base coatings for ships is being conducted.

To the best of our knowledge, the shipbuilding and repair industry has not installed carbon absorption or inceneration facilities on paint buildings. The economic impact is such that these are impractical to date.

The shipbuilding and repair industry is unique in that all painting cannot be carried out "under roof."

Practical regulations, to minimize the insult to environment, should consider the constraints of the industry to which they apply.

Fifteen minutes does not allow very much time to elaborate on our efforts, however I want to take this opportunity to thank the senior management of each of the shipyards represented on our panel. It is essential that the shipbuilding and repair industry work together when addressing regulations, particularly during the comment period, to assure that the economic impact of the regulation will not jeopardize our industry's ability to be competitive in the world market. One of the most significant items achieved by a committee of this type is the rapport developed **between** our counterparts regarding exchange **of** information on day-to-day problem solving.

SP-2 - OUTFITTING AND PRODUCTION AIDS

Louis D. Chirillo
Research and Development Program Manager
Todd Pacific Shipyards Corporation
Seattle, Washington

Mr. Chirillo is currently responsible for the management of outfitting and production aids projects for the national shipbuilding research program.

He holds degrees from Massachusetts Institute of Technology, University of Louisville, and the U.S. Merchant Marine Academy. Mr. Chirillo's past experience includes project engineer of construction on USNS Hayes, and new construction, ship repair and operation with the U.S. Navy.

ABSTRACT

The presentation given by L. D. Chirillo, Chairman SNAME Panel SP-2, was a preview of the book "Product Work Breakdown Structure - November 1980". It describes how the logic of Group Technology is effectively applied by Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI), to ship construction. As the book will soon be distributed to U.S. shipbuilders, it is not incorporated herein.

However, the following interim report is related, and current, research is pertinent because it addresses IHI's effective application of Group Technology to "Fabrication Ship Planning".

Subj: Interim report for NSRP "Fabrication Shop Planning", SAI Project #1-103-02-833, Todd Seattle, P. O. PS-28444

Phase I of the subject project is complete. This phase consisted of two basic steps. First, a literature search and second, a review of current U.S. shipyard practices.

The literature search yielded a list of documents relating to applications of Group Technology (GT) and/or derivative methods, such as family manufacturing, which might serve as background to this project. Enclosure I is a listing of publications available and is annotated to indicate those titles actually reviewed. Two of the articles listed are in Japanese. An attempt will be made to have these translated as they appear to deal with a review of GT applications in Europe, the U.S. and Japan.

It is important to recognize that Group Technology is a management philosophy as opposed to a manufacturing technique or strategy. GT encompasses activities beyond manufacturing and include processes, organization and informational aspects of a company.

At the heart, of Group Technology is the goal of organizing and assigning work so that common solutions can be applied to common problems throughout the design, planning, material procurement, fabrication and assembly processes. The natural result is more effective mechanization in fabrication, a design-planning-procurement process which inherently promotes productivity and fabrication-final assembly process in which schedules and workloads in system fabrication match assembly needs.

Group Technology concepts have been developed throughout the world. Around 1940, Dr. S. P. Mitrofanow in the U.S.S.R., had advocated a basic idea for grouping machined parts by similarities in production operations. In 1963 Dr. H. Opitz, in Technishe Hochschule Aachen, in Germany, developed a parts classification scheme linking design and manufacturing which he called Group Technology.

This concept, which was useful for small and medium quantity manufacturing, received increasing interest in the machining industry throughout the world. In the U.S., the General Electric Company further developed what they termed "Family Manufacturing."

Dr. Opitz' approach was mainly parts shape-oriented classifications. A manufacturing-oriented parts classification scheme was developed by Dr. K. Tuffentsammer of Stuttgart University. The latter's work, circa 1973, referred to similarities in manufacturing process in terms of turning, milling, grinding and drilling.

In shipbuilding, the Japanese, beginning about 1950, gradually modified their approach from a system-oriented to a product-oriented classification scheme which encompasses basic design through construction processes. This product-oriented approach is similar to that developed by Dr. Tuffentsammer, in terms of logic for grouping by manufacturing process. Whereas most applications of the concepts in the U.S. and other countries have been oriented to specific applications within the manufacturing sector.

The application of techniques to group activities by similarities of processes in shipbuilding has led to higher efficiency, shorter production periods and promoted safer working conditions.

Fabrication activities involve the manufacture of components to be assembled. For example, pipe pieces , vent duct, structural panels, valves, etc. Currently, many components which require similar processes for their manufacture are, in fact, produced in dissimilar ways. For example, fabrication of a pipe piece is planned machine-by-machine or operation-by-operation. With Group Technology, families of parts requiring similar processes for their manufacture can be readily identified. These parts can be grouped in such a manner that a minimum amount of variety is experienced during their fabrication.

Thus, operations on groups of equipment can be planned as a single entity. The result is pre-planned flow lines organized by similar types of fabrication procedures. This is called process categorization. For pipe fabrication it is given the acronym PPFM for Pipe Piece Family Manufacturing. It is a methodology for identification of pipe to be fabrication in terms of diameter, material, geometrical shape, treatment, and so on. PPFM numbers are established by designers and are incorporated on each material list of each pipe piece and identified by work package. PPFM numbers are then grouped by process, fabrication by common flow paths and sorted into physical containers by work package.

These techniques have been demonstrated to provide significant improvements such as simplification of shop control procedures, reduced volume of data, introduction of semi-mass production, increased throughput by reduction in set-up time, reduced scrap, improved machine utilization and reduced work-in-process.

One of the largest potentials .for Group Technology today is in the numerical control field of manufacturing. Similar parts require similar control instructions. Therefore, the programming effort can be significantly reduced.

These methods of grouping do not require the relocation or acquisition of equipment. Flow lines are conceptual and are a means for achieving improved productivity by modifying the procedural approach to the planning for both fabrication and assembly processes. However, analysis of fabricated components by similarities in processing may, in fact, lead to rearrangement of facilities for optimum results and may form the basis for justification of relatively expensive automated equipment.

Many people experienced in manufacturing are familiar with some aspects of Group Technology. They typically view GT as a methodology for coding and classification only, and thus proceed immediately to a review of numbering schemes. It is extremely important, therefore, to recognize that coding and classification systems are merely tools for identifying and grouping parts into families.

Applying GT to fabrication processes in shipbuilding requires an understanding of the logic and principles. For example, one technique, called a manufacturing cell, logically combines all equipment and specialists together in one location to produce a family of components. This may not be practical, however, due to the cost of equipment vs. required volume. A single pipe bender may be able to produce sufficient pipe bends for an entire shipyard's requirements. GT therefore requires tailoring, and each shipyard will necessarily have to develop an individual approach based on their circumstances.

Group Technology applied to fabrication of pipe pieces, such as IHI's PPFM approach, is extremely useful for analyzing required volume and capacity prior to commitment to production. The goal in planning fabrication routing is to enhance productivity by utilizing production line principles. In actual practice, the various steps of fabrication are broken down into steps of cutting, bending, assembling, welding and finishing. Individual steps, thus simplified and specialized, are allocated to prescribed work stations for their execution. At the same time, families of pipe pieces are analyzed to determine the processes to be applied for their fabrication. Schedules are developed for execution of the different processes and are coordinated so as to match the process scheduling to shop operation. Thus, reversals in the direction of work flow are minimized.

Such analyses of fabrication processes and routing of work through a shop is possible only when such factors as fabrication period, man-hours required and fabrication procedure are standardized. For planning actual fabrication in a shop, the families are regrouped so as to take into account similarities not only in shape and normal fabrication procedure, but also other factors relevant to work progress control such as division of work with subcontractors.

Thus, components for actual fabrication are grouped for determining their routing through a shop and are utilized for production control. The families of components identified in design are used principally for other general scheduling requirements. However, identification of components by family permits rapid grouping of components by required process since each family has a pre-defined step-by-step procedure. Actual production work at each stage can be controlled as a group or lot which facilitates control.

Current practice within the U.S. is to work piece-by-piece and operation-by-operation. For example, an individual pipe piece is identified to a systems arrangement drawing. Each individual piece must therefore be planned for installation separately rather than as a group of pipe pieces installed at a particular stage. Control of the assembly (installation) operation by system complicates planning for fabrication by requiring schedules for each piece. Although some yards are beginning to plan assembly work by groups of activities by system (or by pallet), none are utilizing Group Technology techniques to facilitate fabrication. None have implemented flow line concepts for assembly which would also facilitate leveling fabrication shop work loads. One yard has begun to examine flow lines for assembly processes and their efforts will be greatly facilitated by publication and use of the PWBS report.

Another aspect to be considered for fabrication planning is undefined "hot" or "emergency" work. This typically involves repair or overhauls done in the same facility as new construction. In one yard, this undefined work load amounts to 40-50% of the total number of pipe pieces produced. Further complicatinq the situation, all but one of the yards surveyed have separate planning and material control systems but the "undefined" work. This significantly increases the burden on shop managers and results in increased indirect costs to the shipyard. There is a potential for significantly reducing the "undefined" work in overhauls which can directly affect productivity on new construction work that shares the same resources. It is recommended that this aspect be investigated further by examining the potential of utilizing Group Technology approaches to planning for overhauls.

Each of the yards visited expressed an interest in participating in a review of the draft report for this project.

Phase II of the project has been partially completed by receipt of a draft report from IHI describing their approach to fabrication planning. A trip to IHI's Aioi and Kure facilities is planned for early November for review of this report with cognizant managers.

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* Articles Reviewed
** Requires Translation

O-23-1 - **SURFACE PREPARATION AND COATINGS**

John Peart
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NATIONAL SHIPBUILDING AND RESEARCH PROGRAM

Published Reports

(1) Handbook Small Tools for Blasters and Painters

This report defines the principles required for efficient blasting and painting. Specialized cleaning methods from power tool cleaning to closed cycle blasting are discussed, equipment and facilities are described and cost reduction procedures are defined.

(2) Practical Shipbuilding Standards for Surface Preparation and Coatings

This effort developed: (1) a proposed "Shipbuilding Standard for Surface Preparation and Coating" and (2) a Standard Paint and Coating Product Data sheet" and identified the need for a preconstruction conference between the shipyard production and technical sections, the owner representatives and the coating supplier.

(3) Marine Coating Performance for Different Ship Areas

A computer program was developed to compare the effectiveness of the different generic coatings in the different ship areas. The trends indicated by the program was supported by prefailure analysis test results.

(4) Cleaning of Steel Assemblies and Shipboard Touch-up Using Citric Acid

This program confirmed the compatibility of citric acid cleaned surfaces with the present state-of-the-art marine coatings; optimized the cleaning solution and procedure and confirmed the feasibility of a **Phase II** study.

(5) Shipyard Marking Methods

This program identified a marking material meeting the necessary requirements of a durability and overcoatability with marine top coats,

(6) Training Course for Blasters and Painters and Student Handbook

Thirty-six (36) shipyards have participated in the instructor training Program.

Reports Being Edited and Prepared for Publication

(1) Surface Preparation and Coating of Tanks in Closed Areas

(2) Survey of Existing and Promising New Methods of Surface Preparation

Programs Completed - Beports Being Prepared

(1) Evaluation of Water Borne Coatings

(2) Develop a Standard Procedure for Determining Volume Solids of Coatings

Program in Progress

(1) Evaluation of Solventless Coatings

(2) Rust Compatible Primers

(3) Cathodic/Partial Coatings vs Complete Coating in Tanks

(4) Comparison of Surface Profile Measuring Methods

(5) Calcite Deposition in Tanks

FY'79

(1) "Ship Design Considerations for Coating Applications and Maintenance"

(2) "Reclmation of Mineral Abrasives"

(3) "Abrasive Survey" (Proposals received)

FY'80 'Proposed'

(1) "Marine Coating Performance for Different Ship Areas" - Phase II

(2) "Edge Preparation Standard"

(3) "Zone Preparation Guidelines for Preplanning Painting"

A PROGRESS REPORT ON THE REAPS PROGRAM

Douglas J. Martin
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IIT Research Institute
Chicago, Illinois

Mr. Martin is currently responsible for all REAPS program activities at IIT Research Institute (IITRI) and for computer aided design developments within IITRI.

He holds a degree in naval architecture and marine engineering from the University of Michigan. Mr. Martin has 8 years experience in the design and development of computer aided design systems primarily for ship design applications.

ABSTRACT

The REAPS Program is a shipbuilding industry/Maritime Administration cooperative program aimed at developing and implementing largely computer-based technology into U.S. shipyards in support of design and production functions. The organization, activities and current and planned development projects of the program are reviewed.

REAPS PROGRAM STATUS

I. INTRODUCTION

1. REAPS is a 6-year-old program in which shipyard participants and MarAd cooperate in identifying and implementing computer aids and manufacturing technology to enhance U.S. shipbuilding productivity.
2. Origins in numerical control systems.
3. IITRI serves as Technical Manager.
4. 1980 REAPS Participants
   - Bath Iron Works
   - Bethlehem Steel
   - General Dynamics
   - McDermott
   - National Steel and Shipbuilding
   - Newport News Shipbuilding
   - Peterson Builders
   - Sun Ship Inc

II. ORGANIZATION/OPERATION

1. Executive Committee
   - Policy and Planning
   - R&D Recommendation
   - Review Program Progress
   - Review Technical Manager Performance
   - Establish Project Advisory Groups
2. Technical Representatives
   - R&D Project Formulation/Recommendations
   - Review Project Progress
   - Recommend Advisory Group Formation
3. Project Advisory Groups
   - Review Detailed Project Technical Specifications
   - Define Industry Requirements
   - Recommend Modifications to Project

III. ONGOING R&D PROJECT STATUS

1. Rapid Piping Design and Detailing System
   - Prototype software delivered to REAPS by Newport News (NNS) in February 1980.
   - Software currently being installed by IITRI on its PDP 11/45 computer to provide industry demonstration site and allow for end user technical support
2. Interactive Parts Definition System
   - Current development underway at NNS of interactive graphics system to support part geometry definition, part nesting and shop drawing generation.
   - See NNS paper elsewhere in these proceedings

3. Computer Aided Estimating System for Shipbuilding (CAESS)

- CAESS being developed by National Steel and Shipbuilding (NASSCO) to assist estimators in generation and managing the large volume of information used in preparing detailed estimates. Prototype software will be specifically applicable to steam propulsion but system organization/methodology is applicable to all ship "modules".
- CAESS System (Figure 1) consists of three subsystems; Material List Generation, Material Sizing,and Costing and Pricing.
- Material List Generation Subsystem (Figure 2) is used to build and update material lists for systems which may be defined from: Direct User Input, Historical Data, and An Existing List to be Modified.
- Material Sizing Subsystem (Figure 3) for the prototype software is a pipe sizing program. Operation is to Extract unsized system model information from Material Sizing Models File; Apply capacity parameters to size the piping system; Subsequently identify the part numbers of the sized system's components in the Material Size Catalog; Store part numbers in the Ship Estimate Data Base.
- Costing and Pricing Subsystem (Figure 3) is then employed to generate estimate. Component materials costs may come from direct historical prices (found in the Historical Material Requirements Library) escalated using Commodity Price Indices, to some date in the future, most recent buy price, etc. Established component costs to be used on a given estimate may be saved in the Material Parts/Price Catalog. Labor estimates based on the material lists are generated using estimator-specified man-hour ratios (man-hours/unit of measure). Man-hour totals may optionally be spread over time using an estimator-specified construction S-curve. Overhead, profit and other pricing factors may then be applied to establish estimate price.

4. Integrated Hull Form Design

- Purpose is development of an industry-consensus specification for hull form design software; identification and subsequent modification of existing software to meet these specifications.
- Specification covering Hydrostatic, Intact and Damage Stability, Floodable Length, Tank Capacities, Longitudinal Strength and Launching Calculations has been distributed to the projects Advisor Group for review and will subsequently be distributed for industrywide review and comment.

IV. F.Y. 1981 - PROJECTS

1. Product Information System - Task 1: Structural Information Requirements

- Objective is to document the items of information and their relationships used in the functions of structural preliminary and detailed design, lofting, planning and production.
- Shipyards will prepare functional descriptions for these areas.
- Information items and relationships will be identified from these descriptions and documented in terms of a conceptual data base design for future use by structural applications systems.

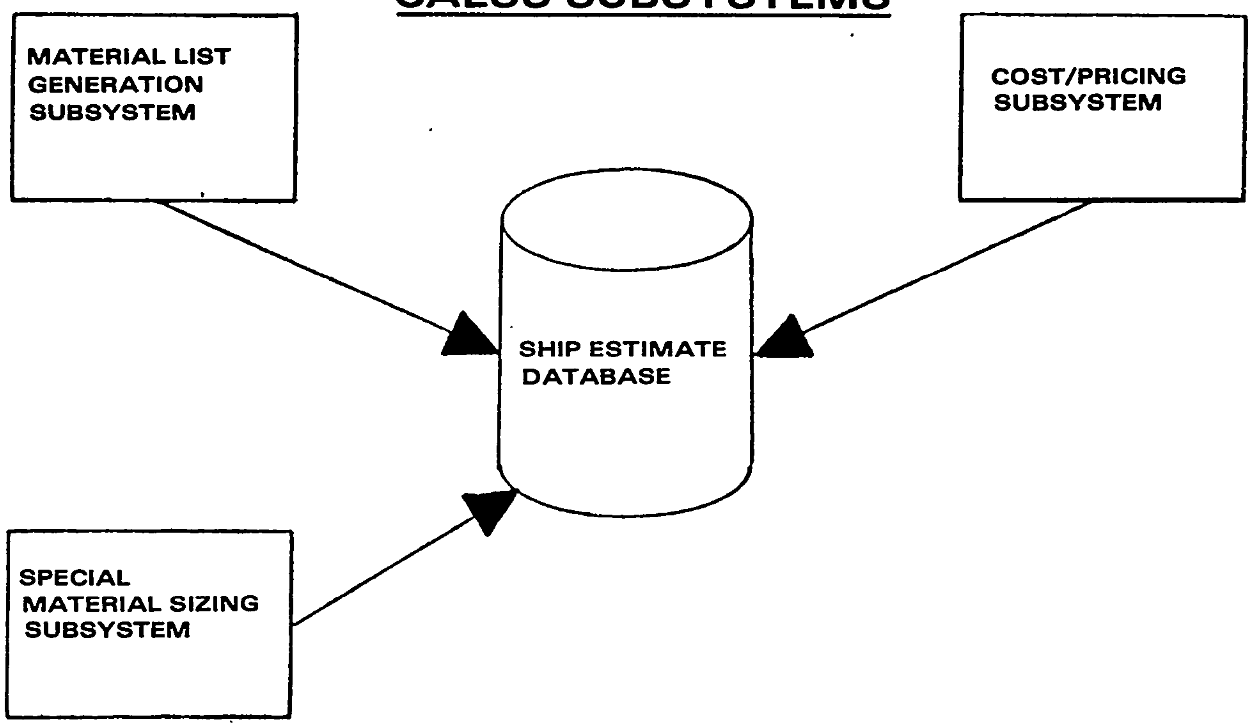
2. Space Arrangements Using Interactive Graphics

- NASSCO is project sponsor and will develop specifications in Phase I of the project for a system to allow designers from various design groups to define system and component layouts within a space and product composite arrangement drawings.
- Phase II of the project will be the development/implementation of all or a portion of the Phase I - specified capabilities.

3. Modular Shipbuilding Information System

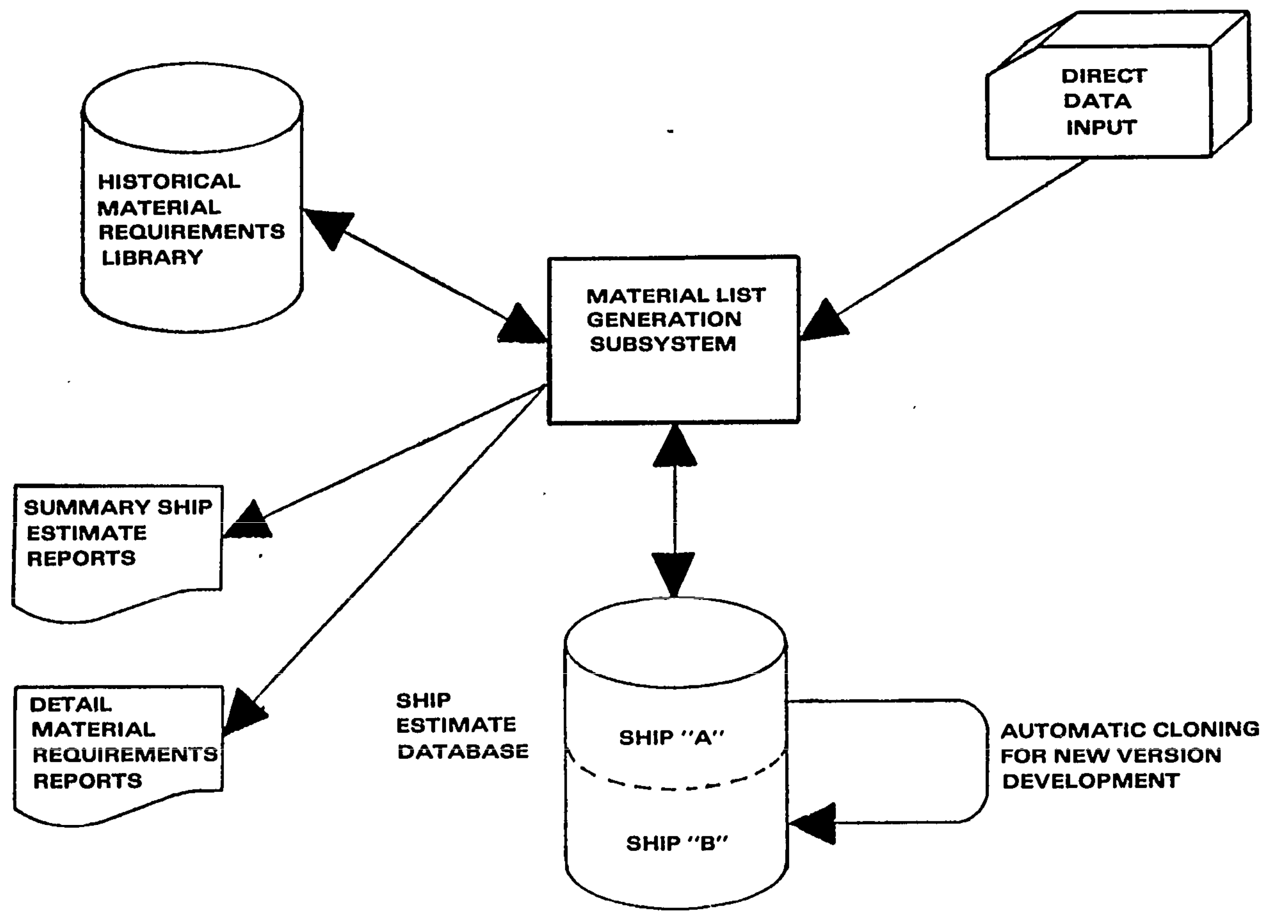
- As part of its REAPS functions IITRI will further investigate the development of a prototype information system which supports zone-based planning, design and production.
- This task will make use of the results of ongoing investigations by Ship Production Committee panels SP-2 and SP-6 and the Levingston-IHI Technology Transfer Program.

CAESS SUBSYSTEMS



The Computer Aided Estimating System for Shipbuilding CAESS is being developed by National Steel and Shipbuilding Co. The objective of this effort is to provide a computer based tool for use by estimators which assists them in managing the large quantities of information used in preparing a contract estimate. The prototype system, depicted here, includes software for generation of material lists and cost estimates for steam propulsion plants. However, the material list generation methodology is applicable to the entire ship as is the application of the independent cost/pricing subsystem.

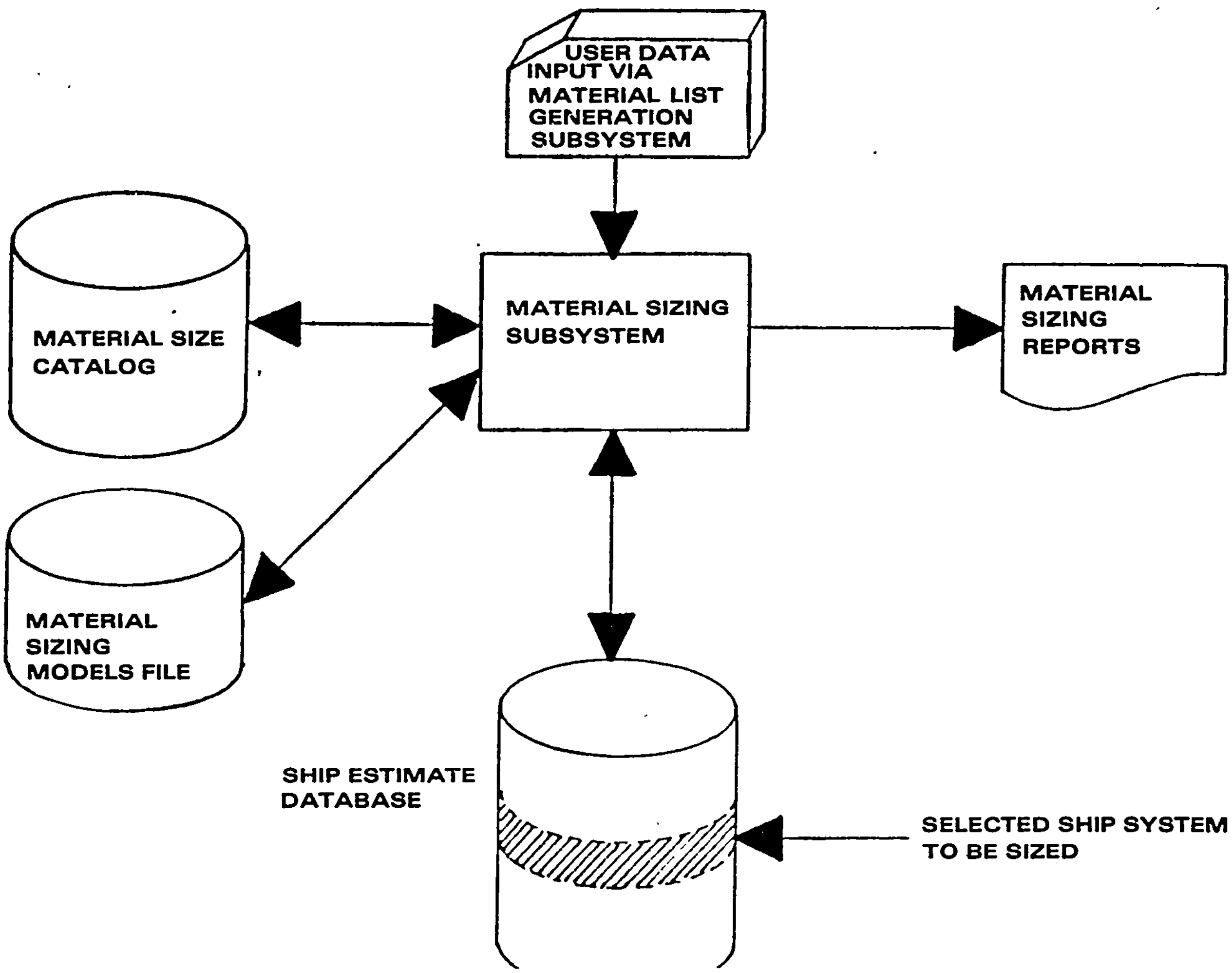
MATERIAL LIST GENERATION SUBSYSTEM



The material list generation subsystem is used to build and edit or update a set of system material lists. Sources of material list information for a given system can be: 1) user input; 2) historical data; or 3) direct copying of an existing system already on the estimate data base or combinations of these.

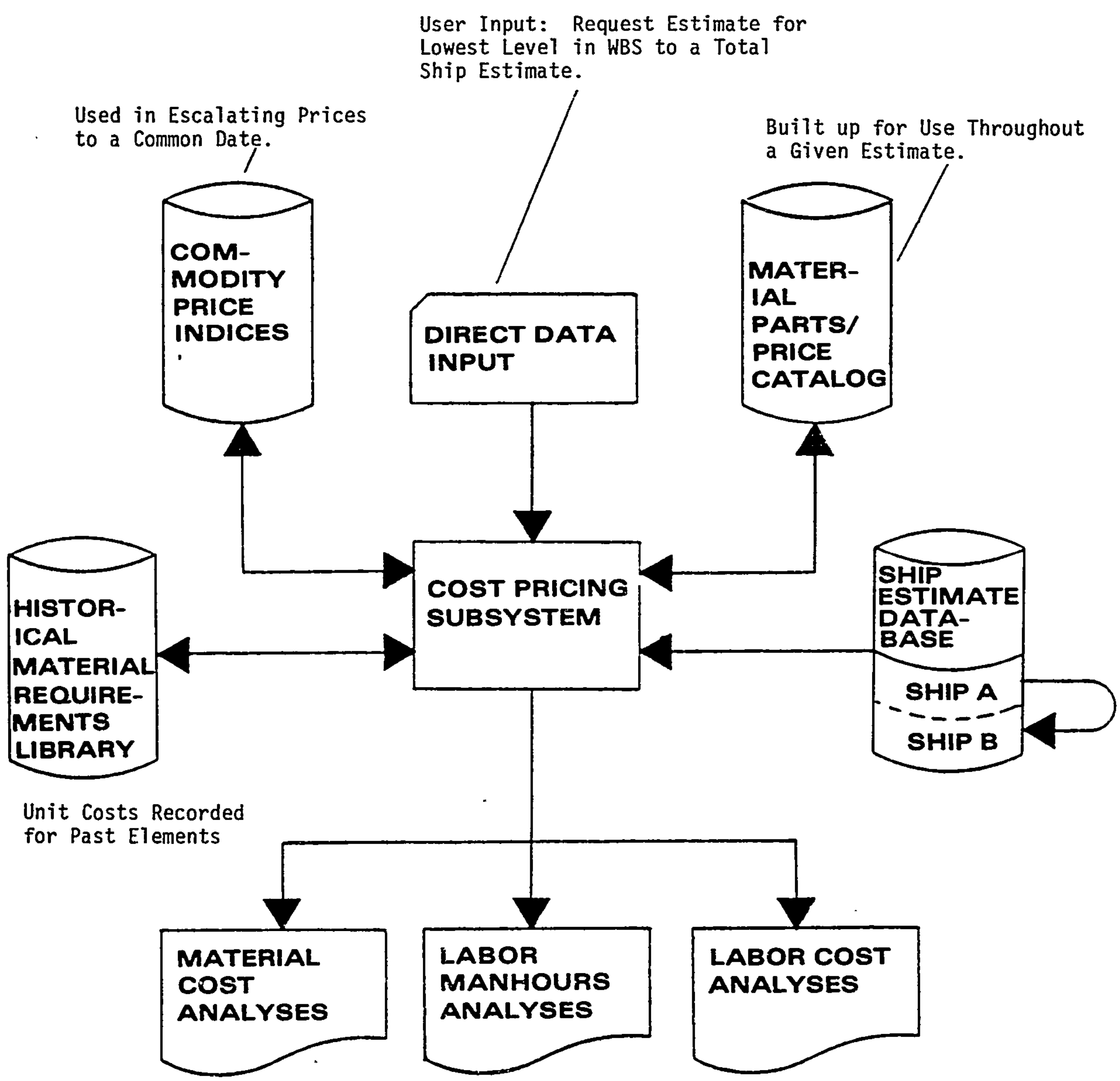
The prototype system's material, sizing subsystem will be a pipe sizing program. In operation the software will extract information on the desired unsized system model from a library of such models, apply capacity parameters to size the material, and, once sized, identify the resulting part numbers of the material from the Material Size Catalog for storage in the Estimate File.

MATERIAL SIZING SUBSYSTEM



Labor estimates derived by applying estimator supplied rates to the appropriate material item quantities to produce labor content to which is applied estimator specified hourly rates. Total labor may be optionally spread overtime by applying an estimator-specified construction S-curve. Overhead and profit rates along with other pricing factors will be applied to allow a total dollar estimate to be generated.

COST PRICING SUBSYSTEM



THE SHIP PRODUCIBILITY RESEARCH PROGRAM
OVERVIEW AND STATUS

John C. Mason
Program Manager
Ship Producibility Research Program
Bath Iron Works Corporation
Bath, Maine

Mr. Mason is program manager for the joint Bath Iron Works/Maritime Administration Ship Producibility Research Program. He also serves as chairman of the Society of Naval Architests and Marine Engineers (SNAME) Panel SP-6 on Standards and Specifications and Panel SP-8 on Industrial Engineering, as secretary of the American Society for Testing and Materials (ASTM) Committee F-25 on Shipbuilding, and is a member of the SNAME Ship Production Committee.

Mr. Mason holds a degree in mechanical engineering from the U.S. Naval Academy and a degree in administration/management engineering from George Washington University.

ABSTRACT

This paper describes the Ship Producibility Research Program, the Bath Iron Works Corp. sponsored element of the Maritime Administration's National Shipbuilding Research Program. The material is presented in three parts:

Part I - Introduction and Background
Part II - The Shipbuilding Standards & Specifications Program
Part III - The Shipbuilding Industrial Engineering Program

THE SHIP PRODUCIBILITY RESEARCH PROGRAM
OVERVIEW AND STATUS

Part I - Introduction and Background

Introduction

Since 1973, Bath Iron Works Corporation has sponsored the Ship Producibility Research Program, one of several elements of the Maritime Administration's National Shipbuilding Research Program. In 1977 it was decided that industry needs and program objectives could best be served by focusing program efforts in two principal areas: (1) Shipbuilding Standards and Specifications, and (2) Shipbuilding Industrial Engineering. During the past three years, significant progress has been made in both areas through the efforts of two new technical panels (SP-6 on Standards & Specifications and SP-8 on Industrial Engineering) under the SNAME Ship Production Committee, working in close cooperation with the American Society for Testing and Materials (ASTM) and the American Institute of Industrial Engineers (AIIE) respectively.

The objective of this paper is to summarize the background, accomplishments to date, current activities, and future plans of the Ship Producibility Research Program.

Background

Between 1973 and 1976 several research projects were conducted under the original Ship Producibility Program concentrating on standardization, improved design and improved shipyard operation. As these initial efforts were completed, it became increasingly apparent

that there were two common denominators for optimizing shipyard productivity improvement. First, the early attempts to develop shipbuilding standards clearly indicated the significant potential of such an approach and the requirement for a nationally coordinated program for standardization in shipbuilding to be successful. Secondly, it was recognized that the various approaches to improved shipyard operations involved many direct functional applications of the discipline of industrial engineering, e.g. methods improvement, work measurement, production control, quality control, facilities, production engineering, etc. Accordingly, efforts began in late 1976 to effectively re-direct the Ship Producibility Research Program to focus on these two areas beginning with the shipbuilding standards and specifications program.

The following events highlight the development of the National Shipbuilding Standards Program:

Castine Conference (June, 1976)

This conference on standards for the U.S. shipbuilding industry was attended by representatives from shipyards, various standards organizations, government and regulatory agencies. The objective of the session was to review the use of standards in other industries and in foreign shipbuilding, to discuss the potential benefits of standardization, and to assess industry interest in supporting a major new U.S. initiative.

The conferees concluded that the development of standards for design, production and procurement was technically and economically feasible, and that a national program should be implemented.

Reactivation of SNAME Panel SP-6 (November, 1977)

SNAME Panel SP-6 on Standards & Specifications was reactivated to serve as the industry's steering committee for the National Shipbuilding Standards Program. Initial MarAd sponsored standards development projects were identified and ASTM was selected as the appropriate forum for ongoing standards development and maintenance.

ASTM Planning Meeting (January, 1978)

Thirty-five representatives from all segments of the shipbuilding industry (shipyards, owners, design agents, vendors, ABS, USCG and the U.S. Navy) met at Philadelphia and agreed that a new ASTM committee on shipbuilding should be formed.

ASTM Organizational Meeting (June, 1978)

More than 175 representatives from every segment of the shipbuilding industry met at Philadelphia and formally established ASTM committee F-25 on Shipbuilding.

The significant accomplishments to date, current activities, and future plans of the shipbuilding standards and specifications program are summarized in detail in Part II of this paper.

In early 1978, the Ship Producibility Research Program and the American Institute of Industrial Engineers sponsored a Shipbuilding Industrial/Production Engineering Workshop which confirmed the feasibility of significant productivity improvements in shipyards through the application of proven industrial engineering techniques. In that same year, the Industrial Engineering Panel (SP-8) was established under the SNAME Ship Production Committee to serve as the shipbuilding industry's principal advisory group for implementation of the workshop's highest priority consensus recommendations. The number one priority identified was the application of basic methods engineering and work measurement techniques.

In late 1979 work on this high priority area commenced with the Phase I Shipyard Methods/Labor Standards Development Program, involving six major shipyards and H.B. Maynard & Co., Inc. - a world leader in management and industrial engineering consulting. At the same time, programs were initiated to increase shipyard management awareness of industrial engineering through (1) a series of AIIE executive briefings, and (2) a series of shipyard production control workshops.

The very significant accomplishments to date, current activities, and future plans of the shipbuilding industrial engineering program are summarized in detail in Part III of this paper.

SP-6 -THE SHIPBUILDING STANDARDS AND SPECIFICATIONS PROGRAM

Samuel Wolkow
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Mr. Wolkow is a project engineer responsible for administration of the standardization portion of the Ship Producibility Research Program, and also serves as secretary of SNAME Panel SP-6.

Mr. Wolkow attended New York University, majoring in mechanical engineering, is a registered professional engineer, and has more than 40 years experience in,the shipbuilding industry.

Part II - The Shipbuilding Standards & Specifications Program

Role: The principal role of SNAME Panel SP-6, "Standards & Specifications," is to coordinate the National Shipbuilding Standards Program effort. Additionally, SNAME Panel SP-6 and the BIW/MarAd sponsored program play an important role in providing a "pump-priming" function for voluntary standards development of ASTM Committee F-25 on Shipbuilding. As a result, MarAd/Industry support has accelerated the development of 3-4 times as many standards as would be possible through strictly voluntary consensus action. It has been conclusively demonstrated that a coordinated effort to develop, maintain, and apply shipbuilding standards is necessary for the U.S. shipbuilding industry.

Scope: The scope of Panel SP-6 is to act as the U.S. shipbuilding industry's steering committee for the National Shipbuilding Standards Program and to set shipyard plans and priorities for standards development, and through the SNAME Ship Production Committee, recommend cooperative MarAd/Industry cost-shared projects which will accelerate direct benefits to the industry.

Recently, more shipyards are expressing an interest in participating in MarAd cost shared projects to adopt and implement innovative approaches to shipbuilding techniques, e.g., zone outfitting, accuracy control, pre-outfit module construction, etc., and in every instance, standards have surfaced as an essential component of the more productive systems.

Membership: Since its activation late in 1977, membership on SNAME Panel SP-6 has increased to ten major shipyards plus senior management personnel from the U.S. Navy (NAVSEA) and the Maritime Administration.

It is significant that several of the existing member shipyards are placing increased emphasis on standardization activities, and many other yards either have or are planning to initiate internal standards programs.

It is anticipated that as many as 4-6 additional shipyards will have applied for formal membership on SNAME Panel SP-6 by the time this presentation is made.

CURRENT MEMBERSHIP SNAME PANEL SP-6

Avondale Shipyards	Quincy Shipbuilding Division
Sun Ship, Inc.	Bethlehem Steel/Sparrows Pt.
Maritime Administration	Davie Shipbuilding, Ltd.
Wiley Manufacturing Co.	NASSCO
NAVSEA	Newport News Shipbuilding
Levingston Shipbuilding	Bath Iron Works Corp.

Prospective New Members

Litton Industries Ingalls Shipbuilding Division	General Dynamics Corp. Electric Boat Co.
Marinette Marine Corp.	Bay Shipbuilding Corp.
Peterson Builders, Inc.	Tacoma Boatbuilding Co.

Prospective members have been reminded that the benefits that can result from cooperative Maritime/Industry cost shared projects are significant, ranging from keeping current on progress and developments to actively participating in MarAd funded projects which not only serve industry needs but also have direct application for the individual yard involved.

ASTM Committee F-25

Role: First, the American Society for Testing and Materials (ASTM) is simply a non-profit management system for the development of voluntary consensus standards. The ASTM staff itself numbers fewer than 100 people and, in fact, voluntary industry representatives serving on the Committee are ASTM. In the late 1960's the ASTM charter was modified to include the development of standards for products, systems, and services in addition to the more familiar material standards such as specifications for steel, non-ferrous metals, plastic, etc. It should also be noted that ASTM is the world's largest source of voluntary consensus standards and that all ASTM standards are submitted to ANSI[2] (the American National Standards Institute) for parallel approval as American National Standards (formerly ASA standards). Recognizing the problem of semantics surrounding the word "standard," ASTM well uses it as an adjective in conjunction with five types of standards - specifications, practices, definitions, classifications, and test methods.

[2]ANSI is not in the business of writing standards, but performs the function of national coordinator; ASTM is the major standards writing organization.

Scope: The scope of Committee F-25 on Shipbuilding is to develop standard specifications, test methods, definitions and practices for design, construction, and repair of marine vessels. The committee will coordinate its efforts with other ASTM committee and outside organizations having mutual interests.

Membership: On May 31-June 1, 1978 over 175 senior representatives from all segments of the shipbuilding industry (shipbuilders, owners/operators, design,agents, major vendors, regulatory and government agencies, and academia) met at ASTM Headquarters in Philadelphia and officially organized the new ASTM Committee F-25 on Shipbuilding.

To date, about 180 individuals have established official membership status. In many instances several people from a single organization actively participate in committee activities behind the one official representative.

The current slate of officers and the organization of Committee F-25 is summarized below:

OFFICERS

Chairman	R. J. Taylor	EXXON International Co.
1st Vice Chairman	E. A. Schorsch	V.P. Bethlehem Steel Co.
2nd Vice Chairman	Radm. E. J. Otth	USN NAVMAT
3rd Vice Chairman	H. F. Greiner	Sealol, Inc.
Secretary	J. C. Mason	Bath Iron Works Corp.

SUBCOMMITTEE OFFICERS

F-25.01	Materials	J. C. West	Beth. Beaumont
'F-25.02	Coatings	*T. Krehnbrink	Sun Ship, Inc.
F-25.03	Outfitting	N. M. Stiglich	Eness R & D Corp.
F-25.04	Hull Structure	T. Krehnbrink	Sun Ship, Inc.
F-25.06	Ship Control & Automation	F. J. Kennedy	NAVSSES PHILA
F25.07	General Support Requirements	S. H. Bailky	Avondale Shipyards
F-25.08	Deck Machinery	D. G. Pettit	NAVSEA
F-25.10	Electrical/Electronics	F. E. Anderson	NAVSEA
F-25.11	Machinery	B. J. Walsh	NAVSEA
F-25.12	Welding	*S. Morrison	General Dynamics/E.B. co.
F-25.13	Piping	H. F. Greiner	Seal01

*Interim Status

Current Status

SNAME/MarAd/Industry Program

This program derives its impetus from the cooperation provided by participating members of the shipbuilding industry acting through the Society of Naval Architects and Marine Engineers' Ship Production Ccmmittee in recommending projects to be accomplished under a cost sharing plan administered by the Maritime Administration and managed by major sponsoring shipyards.

Bath Iron Works Corporation, as manager of the Ship Producibility Program, currently has under contract with five leading U.S. shipyards twelve separate projects which comprise over fifty individual tasks. These involve such elements as Shaft Alignment Standards (3), Construction Standards Group I (9), Mechanical Design, Construction Standards Group II (8), HVAC Design/Construction Standards (10), Outfit Construction Standards (6), Standard Piping Material Schedule,

Construction Tolerance Standards, Weld Defect Tolerance Study, Standards Program Long Range Plan, Mechanical Design/Construction Standards Group III (7), Standard Piping Diagrams (2), QA/QC Standards, and Development of Industry Standards (5) (Note 1).

It is becoming increasingly apparent as the standards program develops that short term accomplishments are providing support and momentum for long range goals and objectives.

For example, in June, 1980, Dr. Les Sandor of Sun Ship, Inc. completed a work (Task S-22) on "Weld Defect Tolerance Study." As a result of his investigations, Dr. Sandor proposes a fitness for purpose approach for resolving the problem of correcting welding deficiencies by such innovative concepts as Quality Band and Quality Control Systems Loop. Dr. Sandor's study provides a definitiire analysis of weld discontinuities on the vessel's structural integrity and concludes that the preponderance of weld repair activity in the commercial sector of the U.S. Shipbuilding Industry involves slag inclusions and porosity, which have the least harmful effect on the hull structure. He therefore proposes that first priority be given to the establishment of new, improved weld acceptance standards with regard to these defects. Accordingly, efforts have been jointly undertaken by SNAME Panels SP-6 and SP-7 in conjunction with ASTM technical subcommittee F-25.12 (Welding) to start development of a draft standard based on Dr. Sandor's work. It is estimated that savings amounting up to $1 million/ship can be realized by eliminating the need to correct such innocuous weld defects as slag and porosity.

Note 1 - The individual status of all standards being developed under the SNAME/MarAd program is summarized in attachment (1) hereto.

Another project currently underway involves a study of construction tolerance standards (Task S-21A) also under subcontract to Sun Ship, Inc. The scope of work for this task is to investigate and summarize the effect of fit-up problems, alignment, and unfairness on the integrity of the hull structure, also on a fitness for purpose philosophy. The result of this work is expected to provide the basis for a follow-on contract intended to produce standards defining acceptable construction tolerance criteria. It is further anticipated that this study will lead to an investigation of rework requirements involving cosmetic repairs which are highly labor intensive and time consuming to accomplish, and like slag and porosity weld defects, have little or no harmful effect on the integrity of the hull structure. An estimate of savings that can be achieved by eliminating rework of a cosmetic nature amounts to several million dollars/ship.

Future Plans

The long range plan for FY-80 (Task S-29) is intended to be the most ambitious and intensive effort attempted to date in the U.S. Standards Program. Its scope and magnitude focuses on a program designed to develop a new generation of standards addressing shipyard/ industry needs and priorities.

Since it is percieved to be a pre-accepted industry consensus plan, active coordination with both SNAME Panel SP-6 and ASTM Committee F-25 will be required to determine specifically what the thrust and direction of the effort shall be, priorities to be ordered, actions required and responsibilities to be assigned.

The rationale for this project derives from the success of the IHI/Levingston Technology Transfer Program, the benefits gained and advantages realized from pre-outfitting, zone outfitting and modular construction techniques, and the conclusions reached from the 1979 Ship Production Committee survey of Japanese shipbuilding technology.

As suggested in the paper presented to the Metropolitan Section (NYK) of SNAME by Messrs. Tim Colton and Yukinori Mikami, the long range plan will probably address standards development in such areas as engineering and design procedures, planning and production control processes, facilities and industrial engineering techniques, quality assurance, and perhaps even industrial employment methods. BIW as the lead yard/program manager will select proposals from major Japanese shipyard/consulting firms to survey U.S. yards, organizations, facilities, personnel and practices. The result will be to suggest standards development/priorities needed to support an ongoing long range plan to optimize both near and long term benefits, which will generate industry-wide participation and support. The intention of Panel SP-6 is to focus the program on shipyard application, addressing such areas as zone outfitting, pre-outfit module construction, accuracy control, quality control, etc.

V. Current Status - ASTM Voluntary Standards Development

Development of consensus standards within formal due process requirements of ASTM is a deliberate and time-consuming process.

Initially, a task group of 2-5 people is formed to do the necessary investigative work and then prepare an initial draft which is reviewed by the cognizant technical subcomittee through a balloting procedure.

If the draft is approved by two-thirds of those returning their ballots (a minimum of 60% of boting interests must return ballots), the document proceeds to the main committee ballot. Here 90% of those returning ballots (and again a 60% return is required) must approve the document. It then proceeds to the Society ballot where a minimum of 50 ballots must be cast and a 90% affirmative vote is required to make it an approved ASTM standard.

A single negative ballot at any stage of the process returns the proposed standard to the originating technical subcommittee for resolution.

This procedural description provides greater significance to the advanced status of the ASTM voluntary standards development and also emphasizes the role of the BIW/MarAd program and SNAME SP-6 activities in accelerating standards availability to the industry (Note 2).

Note 2 - The individual status of all standards now being voluntarily developed by ASTM Committee F-25 is summarized in attachment (2) hereto.

On July 3, 1980, Sam Bailey of Avondale Shipyards, Inc. had the distinct honor of developing the first standard to complete the Society balloting procedure. This standard, for a five and ten gallon engineer's oil dispensing tank, will be published in the ASTM 1981 edition of the Book of Standards, Part 46 (Sub. 07).

Coincidentally, the ASTM Committee on Publications intends to restructure the Annual Book of ASTM Standards, 1982 edition, from 48 to 63 parts. By that date, Committee F-25 will have met the minimum requirements for having its own Book of Standards assigned, and has formally notified the Publications staff of this fact.

VI. Future Plans

In May, 1980, Committee F-25 held its semi-annual meeting in Denver, CO. A unique feature of this meeting was a shipbuilders' workshop which was designed to provide a forum for shipyard representatives to present their problems, concerns, and recommendations for standards development priorities to the Main Committee and technical subcommittees for their review, consideration, and action. This workshop proved to be so productive and mutually beneficial to all concerned, that similar workshops are being planned for ship owners/operators and design agents. As the MarAd/Industry long range plan matures, it is anticipated that numerous recommendations will cascade to Committee F-25 for due process development as National standards. ASTM, as the National Standards writing organization, validates the efforts of SNAME Panel SP-6 and provides national recognition and prestige to the shipbuilding standards effort.

The long range goals of Committee F-.25 formulated at the May, 1980 meeting in Denver were defined as:

- Developing and elucidating a policy position regarding Government participation in the work of F-25.
- Coordinating the development of long range planning goals and objectives with SNAME Panel SP-6.
- To increase emphasis on public relation activation:
  NSSP Status Report No. 1
  Weld Defect Tolerance Study ASNT Journal
  Adm. Lisanby/John Haas paper in ASNE Journal
  ASTM Book of Standards - Shipbuilding
  ABS Surveyor
  ASTM/SNAME October, 1981 Symposium

VII. U.S. Navy Participation/Support

The Navy Department's participation in the voluntary consensus standards program is most encouraging and supportive and is worthy of special commendation. The Navy Department has fully complied with the spirit and intent of the directives contained in OMB-A119.

As an example, the Navy is currently studying the standards program with the view towards official DOD acceptance and eventual inclusion in the Navy General Specifications for Building Ships. Further to this effort, Admiral Lisanby and Mr. John Haas have written a paper on commercial standards application to Naval Design and Construction procedures. Also, NAVSEA has established a new office in the Shipbuilding Directorate that is chartered to improve the quality and reduce the cost of repair and construction in the private and public sector ship repair and construction activities. The Director of the new office is Capt. Robert Christensen, USN.

Other activities that the Navy has underwritten in support of the ASTM voluntary standards development program include:

- The establishment of a Hull and Machinery engineering forum to discuss industry needs and how these needs can best be served.

- Reactivation of the ASME Boiler marine conference.

- Participation and representation on all F-25 technical subcommittees and most SNAME activities.

VIII. OMB Circular Letter A119

OMB-A119, "Federal Participation in the Development and Use of Voluntary Standards" provides executive branch policy for agencies working with voluntary standards developing bodies. It also establishes policy to be followed in adopting and using such standards in procurement activities.

OME-A119 states the general policy of the Federal Government is to:

- Rely on voluntary standards with respect to Federal procurement whenever possible and consistent with the law.

- Participate in activities of voluntary standards bodies when such is in the public interest.

- Coordinate agency participation in voluntary standards bodies to insure maximum effectiveness of participation.

OMB-A119 establishes criteria for identifying voluntary standards developing bodies that meet minimum requirements for-due process:

- List of accredited organizations to be maintained by the Secretary of Commerce.

- Listing is precondition to Federal participation.

- Basic requirements are: open access to participation; advance notice; due process; and adequate recordkeeping procedures.

OMB-A119 emphasizes that voluntary standards are to be given preference in government procurement activities.

SP-8 -THE SHIPBUILDING INDUSTRIAL ENGINEERING PROGRAM

Joseph R. Fortin
Project Engineer
Ship Producibility Research Engineer
Bath Iron Works Corporation
Bath, Maine

Mr. Fortin is a project engineer responsible for administration of the industrial engineering portion of the Ship Producibility Research Program, and also serves as secretary of SNAME Panel SP-8.

Mr. Fortin holds a degree in marine transportation from the Massachusetts Maritime Academy.

PART III - THE SHIPBUILDING INDUSTRIAL ENGINEERING PROGRAM

Introduction

As a result of the three-day Atlanta Workshop in 1978, the Shipbuilding Industrial Engineering Panel SP-8 of the Society of Naval Architects and Marine Engineers was established to act as the shipbuilding industry's steering committee for a national industrial engineering effort. Specifically, SNAME Panel SP-8 was tasked to:

- Establish a consensus priority list of problem areas for a solution:
- Solicit and review proposed industrial engineering research projects which address the problem areas;
- Provide,continuing program guidance and overview;
- Publish and disseminate research results to the industry and aid in the understanding of such results:
- Maintain a flexible and continuing program with built-in redirection capability to address new problems as they arise;
- Maintain an up-to-date awareness of shipbuilding and industrial engineering technology;
- Schedule annual technical meetings for industrial engineers in shipbuilding;
- Develop and organize a program of training for shipyard management and industrial engineering.

Two consensus high priority areas selected by SNAME Panel SP-8 for immediate action were (1) Methods Engineering/Labor Standards Development and (2) generally increasing shipbuilding management awareness of the scope and potential of basic industrial engineering techniques in shipbuilding.

Membership: SNAME Panel SP-8 is made up of approximately 25 active members who represent both the large and small shipyards in the United States. Represented are: Bath Iron Works, National Steel & Shipbuilding, Newport News Shipbuilding, Bay Shipbuilding, Peterson Builders, Bethlehem Steel/Sparrows Point, Sun Ship, Jeffboat, Equitable Shipyards, Levingston Shipbuilding, Wiley Mfg., Avondale Shipyards, Marinette Marine, and Norfolk Shipbuilding & Drydock.

Panel members meet regularly to coordinate their efforts and set goals and priorities for the industrial engineering program. With significant support from the Maritime Administration, the panel has implemented priority programs toward the goal of increased productivity through the application of basic industrial engineering concepts.

As priority number one, Phase I of the Shipyard Methods/Labor Standards Development Program was implemented in late 1979. It was recognized that the necessary expertise for a comprehensive labor standards development program did not currently exist within the shipbuilding industry. Therefore, proposals were solicited for the performance of an effort that would result in a coordinated labor standards development program tailored to the needs of the shipbuilding industry.

The H. B. Maynard and Co. proposal was selected as the best suited to meet the needs of the program. The purpose of their effort was to provide training and consulting services for the six initial shipyards to develop predetermined motion time system standards using the Maynard Operation Sequence Technique (MOST) System. Significant productivity improvements were anticipated through the development and application of these methods/process

standards.

The participating yards and functional areas addressed during Phase I are:

BIW - Fabrication and sub-assembly

NASSCO - Panel line and sub-assembly

Bay Ship - Hull erection

PBI - Pipe shop

Sun Ship - Blast & paint shop

NNS - Development of the maxi MOST system

One of the products of this program will be a published Work Management Manual for each functional area. These manuals will be shared by participating shipyards, thereby accelerating industry-wide application and benefits.

While the'labor standard data developed during this phase of the program will ultimately provide an extremely valuable input in such areas as planning, scheduling and production control, benefits from methods improvement have already been realized. Ecr example:

- 25 to 30% productivity improvement in crane utilization from the use of time studies to identify delays. As a result, more emphasis was placed on planning the crane moves and the riggers were prompted to be better prepared and set up for each crane usage.

- 10 to 40% productivity improvement in the shipboard assembly and installation area. This resulted from methods analysis performed while defining the process used in work measurement. The end result was using the most efficient process which also established proper manning requirements and a better definition of material requirements, palletizing, and staging needs. The productivity improvement figure was derived from measurement of the process both before and after methods improvements.

- 15% productivity improvements were realized in the foundation assembly area. Some examples of methods improvements contributing to this overall productivity improvement rate are:

- Installation of jib cranes to service work tables to eliminate the delays caused by using the bridge crane.

- Setting up a clipboard logging system for fabricated parts replacing random storage, thus improving the flow of parts to the assembly work area.

- Method change in fabrication of deck beam cutouts from burning to more efficient punching out of cutouts with a punch press. This process also reduces slag grinding time at assembly.

- Switching from stick welding to more efficient fluxcore welding with the introduction of new fluxcore equipment.

- Relocation of various equipment and work benches to allow a better flow of material.

These conservative estimates from actual shipyard documentation are but a sampling of some of the more obvious methods improvements made during the initial phase of the program.

Phase II of the Shipyard Methods/Labor Standards Development Program (1981) will be a follow-on to Phase I with several significant additions. First, Bethlehem Steel/Sparrows Point has been added as the seventh shipyard actively participating, and seven new areas have been selected for detailed methods engineering review and development of labor standard data. Phase II yards and task areas include:

BIW - Main Assembly

NASSCO - Plate Shop

NNS - Blast & Paint/Platen & Dock/Maxi MOST

Sun Ship - Sheetmetal Shop

Bay - Application & Transferability of WMM's

Peterson - Electrical Shop

BSC/SP - Temporary Staging

Secondly, Phase II will also include a one-year test and evaluation period for the H. B. Maynard & Co. MOST Computer System. It is anticipated that this system will greatly enhance the industrial engineer's capability to develop, maintain, **and** update standards as new methods or changes occur. Some additional anticipated benefits are:

- Improving the productivity of the I.E.
- Generating uniform information and data for faster, more consistant production planning and control.
- Increasing savings/cost ratio for the I.E. function and profitably for the shipyards.

By the end of Phase II it is anticipated that sufficient justification will have been provided for participating shipyards to sustain ongoing methods/standards programs. Preliminary implementation plans are now being developed to ensure the maximum benefit from the standard data being generated in each yard.

The second consensus high priority area selected by SNAME Panel SP-8 was "generally increasing shipbuilding management awareness of the scope and potential of application of basic industrial engineering techniques in shipbuilding." To this end, a professional presentation entitled "Industrial Engineering Applications in Shipbuilding" has been developed by the American Institute of Industrial Engineers (AIIE) to support the program. These presentations are being provided in the form of executive briefings to upper and middle management throughout the shipbuilding industry. The four principal objectives of these presentations are:

1. To briefly describe industrial engineering and its relationship to productivity improvement.

2. To describe in some detail the most cost effective industrial engineering approaches and priorities for implementation.

3. To indicate to management the support required and benefits which should be anticipated from implementation of various techniques.

4. To highlight progress already being made through application of methods engineering and work measurement techniques.

Another priority project included in Phase I of the program is the development of a two-day Production Control Workshop. This workshop is based on the"Manua1 on Planning and Production Control for Shipyard Use" published by the Ship Producibility Research Program in 1979, and it will be offered to several interested shipyards during late 1980 and early 1981.

The primary objective of these workshops is to relate production control to industrial engineering and to provide specific guidance for follow-on implementation of labor standard data.

Finally, another significant area being coordinated by SNAME Panel SP-8 is Accuracy Control. Recently, a special task group on accuracy control has been established with the primary objective of gathering, correlating, and disseminating relevent data to interested yards.

In summary, significant accomplishments are being achieved through the hard work and dedication of SNAME Panel SP-8, all made possibly by the backing and support of the Maritime Administration and AIIE. In the immediate future, this program promises to contribute continued productivity improvement in the shipbuilding industry through the priority application of industrial engineering techniques.

NATIONAL SHIPBUILDING STANDARDS PROGRAMS

DATE: SEPT. 1980

STATUS OF SNAME/MARAD SPONSORED SHIPBUILDING STANDARDS PROGRAMS

PROGRAM	SPONSOR	STATUS: TECHNICAL DEVELOPMENT	DRAFT	F25 SUB-BALLOT	F25 BALLOT	ASTM BALLOT	FINAL PUBLICATION	REMARKS
SHAFT ALIGNMENT STANDARDS	TASK S-21							
I. Geared Steam Turbine; Inboard Shafting	SUN/F-25.11	OCT. 1978	OCT. 25, 1979	JAN. 9, 1980				
II. Slow Speed Diesel, Inboard Shafting	SUN/F-25.11	FEB. 1979	JUNE, 1980					
III. Geared Steam Turbine; Outboard Shafting	SUN/F-25.11	JULY 1979	APRIL 1, 1980					
CONSTRUCTION STANDARDS, GROUP I	TASK S-23							
Sleeve Type Pipe Couplings	BIW/F-25.13	SEPT. 29, 1978	FEB. 2, 1979	APRIL 30, 1979 & MARCH 24, 1980	NOV. 19, 1979 & MARCH 24, 1980	JUNE, 1980		
Modular Gage Boards	BIW/F-25.13	SEPT. 29, 1978	FEB. 22, 1979	JULY 16, 1979	MARCH 3, 1980			
Gage Piping Assemblies	BIW/F-25.13	SEPT. 29, 1978	FEB. 18, 1979	SEPT. 24, 1979 & MARCH 3, 1980	JULY 25, 1980 MARCH 3, 1980			
Weld Joint Design for Shipboard Piping	BIW/F-25.13	SEPT. 29, 1978	MARCH 9, 1979	SEPT. 24, 1979	MARCH 3, 1980			
Use of Branch Connections	BIW/F-25.13	SEPT. 29, 1978	MARCH 14, 1979	JULY 16, 1979	MARCH 3, 1980	JUNE, 1980		
Selection & Application of Thermal Insulation on Piping & Machinery	BIW/F-25.13	SEPT. 24, 1978	JUNE 29, 1979	NOV. 12, 1979	MARCH 3, 1980	JUNE, 1980		
Design & Install. of Rigid Pipe Hangers	BIW/F-25.13	SEPT. 29, 1978	AUG. 27, 1979	NOV. 26, 1979	MARCH 3, 1980			
Guidelines for Cleaning/Flushing Ships' Piping Systems	BIW/F 25.13		JAN. 30, 1979 & SEPT. 20, 1979					TECH. SUBCOM. F-25.13 SURVEYED RE: PROCEEDING W/THIS TASK. UNANIMOUS AGREEMENT REACHED TO CONTINUE.
Guidelines for Shipboard Automation Interface Control	BIW/F-25.06		MARCH 8, 1979 & OCT. 3, 1979					DELETED FROM TASK S-23 AS A CONSTRUCTION STD. & DEVELOPED AS A STD. ENGINEERING GUIDELINE INSTEAD.
CONSTRUCTION STANDARDS, GROUP II	TASK S-24							
Selecting Bolting Lengths for Piping System Flanged Joints	NASSCO/F-25.13	SEPT. 1, 1978	OCT. 2, 1978	JUNE 7, 1979	MAY 15, 1980			
Funnels	NASSCO/F-25.13	SEPT. 1, 1978	APRIL 25, 1979	SEPT. 27, 1979	MAY 15, 1980			
Insulated Watertight Bulkhead & Deck Penetrations for Non-ferrous Piping Passing through Steel Structure	NASSCO/F-25.13	SEPT. 1, 1978	APRIL 25, 1979	SEPT. 24, 1979, MAY 15, 1980 & AUG. 13, 1979				
Steel Flanges for Non-ferrous Piping	NASSCO/F-25.13	SEPT. 1, 1978	APRIL 25, 1979	AUG. 13, 1979 & MAY 15, 1980				
Piping System Diagram Preparation, Tables, General Notes, Etc.	NASSCO/F-25.13	SEPT. 1, 1978	MAY 18, 1979	OCT. 22, 1979				
Welded Sleeve for W.T. & O.T. Bkd. & Dk. Penetrations for Ferrous & Non-ferrous Pipe & Tubing	NASSCO/F-25.13	SEPT. 1, 1978	JUNE 19, 1979	AUG. 29, 1979 & MAY 15, 1980				
Commercial Steel Air Receivers	NASSCO/F-25.13	SEPT. 1, 1978	JAN. 11, 1980					
Commercial Steel Potable Water Tank	NASSCO/F-25.13	SEPT. 1, 1978	APRIL 8, 1980					

ATTACHMENT (1)

NATIONAL SHIPBUILDING STANDARDS PROGRAMS

DATE: SEPT. 1980

STATUS OF SNAME/MARAD SPONSORED SHIPBUILDING STANDARDS PROGRAMS

PROGRAM	SPONSOR	STATUS: TECHNICAL DEVELOPMENT	DRAFT	F25 SUB-BALLOT	F25 BALLOT	ASTM BALLOT	FINAL PUBLICATION	REMARKS
NAVAL DESIGN/CONSTRUCTION STANDARDS	TASK S-25							
Goosenecks	BIW/F-25.05	APRIL 17, 1980	JUNE, 1980					Data sent for participant review April, 1980.
Terminals	BIW/F-25.05	APRIL 24, 1980	JUNE, 1980					Data sent for participant review May, 1980.
Fire Dampers	BIW/F-25.05	APRIL 30, 1980						
Control Dampers	BIW/F-25.05	MAY, 1980						
Duct Hangers	BIW/F-25.05	JULY, 1980						
Duct Details	BIW/F-25.05							
WT/NWT Closures	BIW/F-25.05							
Penetrations	BIW/F-25.05							
Drafting Std.	BIW/F-25.05	MAY, 1980						
Volumetric Test Std.	BIW/F-25.05	MARCH, 1980	JUNE, 1980					Data sent for participant review April, 1980. Contract signed Nov. 9, 1979.
OUTFIT CONSTRUCTION STANDARDS	TASK S-27							
Inclined Ladders	SUN/F-25.03	JULY 1980						
Bilge Keel Details	SUN/F-25.03							
Manholes	SUN/F-25.03	JULY 1980						
Rails (open, storm, guard)	SUN/F-25.03							
Mach'y Space Floor Plates and Handrails	SUN/F-25.03	JULY 1980						
Vertical Ladders & Grabs	SUN/F-25.03							
STANDARD PIPING MATERIAL SCHEDULE	TASK S-28 BIW/F-25.13	FEB., 1980	AUGUST 1980					
CONSTRUCTION TOLERANCE STANDARDS	TASK S-21A SUN/F-25.04	APRIL, 1980	JUNE, 1980					Authorized to expend funds allocated to Task S-23. Authorized to expend funds allocated to Task S-21.
NAVY WELD DEFECT TOLERANCE STUDY	TASK S-26 SUN/F-25.12	FEB., 1980						
STANDARDS PROGRAM LONG RANGE PLAN	TASK S-29 BIW/F-25.91							

DATE: SEPT., 1980

NATIONAL SHIPBUILDING STANDARDS PROGRAMS

STATUS OF SNAME/MARAD SPONSORED SHIPBUILDING STANDARDS PROGRAMS

PROGRAM	SPONSOR	STATUS: TECHNICAL DEVELOPMENT	DRAFT REVIEW	F25 SUB BALLOT	F25 BALLOT	ASTM BALLOT	FINAL PUBLICATION	REMARKS
MECHANICAL DESIGN/CONSTRUCTION STANDARDS - GROUP III	TASK S 40							
Valve Label Plates	NASSCO/F-25.1							
Thermometer Connections	NASSCO/F 25.1							
Ovbd. Disch. Conn. Designs	NASSCO/F-25.1							
Lifting Padeye Designs	NASSCO/F-25.1							
Bilge Strainer Boxes	NASSCO/F-25.1							
Orifice Plates	NASSCO/F-25.1							
Selection & Arrangement of Valve Operating Gear	NASSCO/F-25.1							
STANDARD PIPING DIAGRAMS	TASK S-32							
F.O. Service System								
F.O. Transfer System								
QA/QC ACCEPTANCE STANDARDS	TASK S-33 NN/F-25.07							
DEVELOPMENT OF: Repair Standards	TASK S-33A							
Inspection Standards	NN/F-25.07							
Accuracy Cont. Stds.								
Tolerance Standards								
Process Standards								

DATE: SEPT., 1980

NATIONAL SHIPBUILDING STANDARDS PROGRAM

STATUS OF ASTM COMMITTEE F-25 VOLUNTARY STANDARDS DEVELOPMENT

STANDARD TITLE	SUB-COMMITTEE	STATUS: TECHNICAL DEVELOPMENT	DRAFT	F25 SUB-BALLOT	F25 BALLOT	ASTM BALLOT	FINAL PUBLICATION	REMARKS
VERTICAL LADDERS	F 25.03	NOV. 16, 1978	APRIL 20, 1979	OCT. 22, 1979				
JOINER DOORS & FRAMES	F 25.03	NOV. 10, 1978	APRIL 10, 1979					
BERTHS	F 25.03	NOV. 16, 1978	JAN. 25, 1979					
DIESEL INSTRUMENTATION/CONTROLS	F-25.06	APRIL 18, 1979						DRAFT NEARLY COMPLETE.
DISPENSING TANK (5 & 10 GAL.)	F-25.07	OCT. 26, 1978	MARCH 26, 1979	APRIL 20, 1979	FEB. 4, 1980	MAY 29, 1980	JULY 3, 1980	*B/S PART 46, 1981 (SUB. .07)
MOORING WINCHES	F-25.08	MAY 23, 1979	SEPT. 9, 1979					
ANCHOR WINDLASSES	F-25.08	MAY 23, 1979	SEPT. 9, 1979					
ELEVATORS	F-25.08	MAY 23, 1979	SEPT. 9, 1979					
MAIN TURBINE SPECIFICATIONS	F-25.11	MAY 22, 1979						
AUX. TURBINE SPECIFICATIONS	F-25.11	MAY 22, 1979						
CENTRIFUGAL PUMPS	F-25.11	MAY 22, 1979						
H.P. BOLTED BONNET VALVES	F-25.13	JAN. 1979	MAY 1979					DRAFT COMPLETED UNDER NAVSEA SPONSORSHIP & SUBMITTED FOR ASTM F-25 PROCESSING IN LIEU OF DEVELOPING NEW MIL-SPEC
FIBERGLASS PIPE	F-25.13	JAN. 1979	JUNE 1979					
PAINT STANDARD PRODUCT DATA SHEET	F-25.02	JAN. 1979	MAY 1979	JULY 1980				SAME AS ABOVE.

*FIRST F-25 COMMITTEE ON SHIPBUILDING STANDARDS TO BE PUBLISHED.

ATTACHMENT (2)

SNAME SHIP PRODUCTION COMMITTEE

PANEL SP-1 - FACILITIES

PANEL SP-2 - PRODUCTION TECHNIQUES

PANEL SP-6 - STANDARDS & SPECIFICATIONS

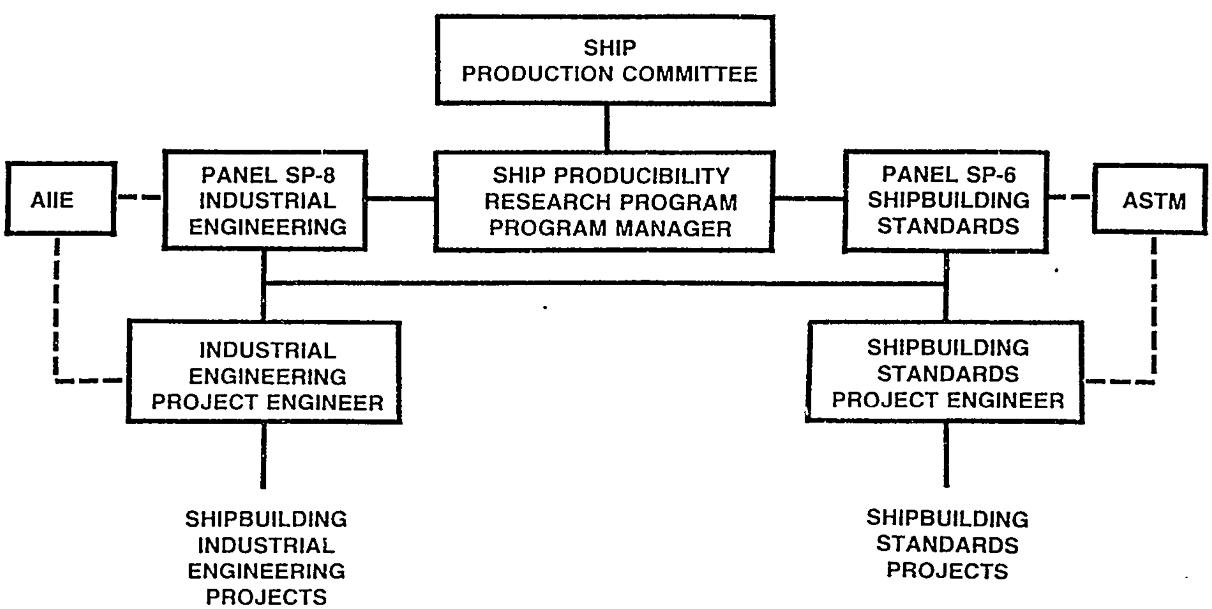
PANEL SP-7 - WELDING

PANEL SP-8 - INDUSTRIAL ENGINEERING

PANEL 0-23-1 - SURFACE PREP. & COATINGS

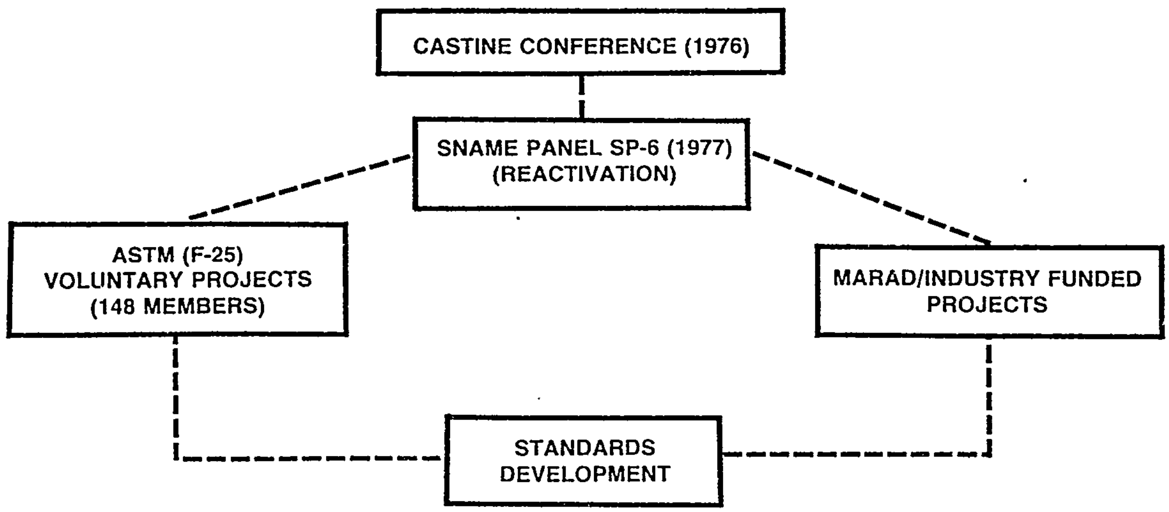
REAPS GROUP - SHIPYARD AUTOMATION

SHIP PRODUCIBILITY RESEARCH PROGRAM



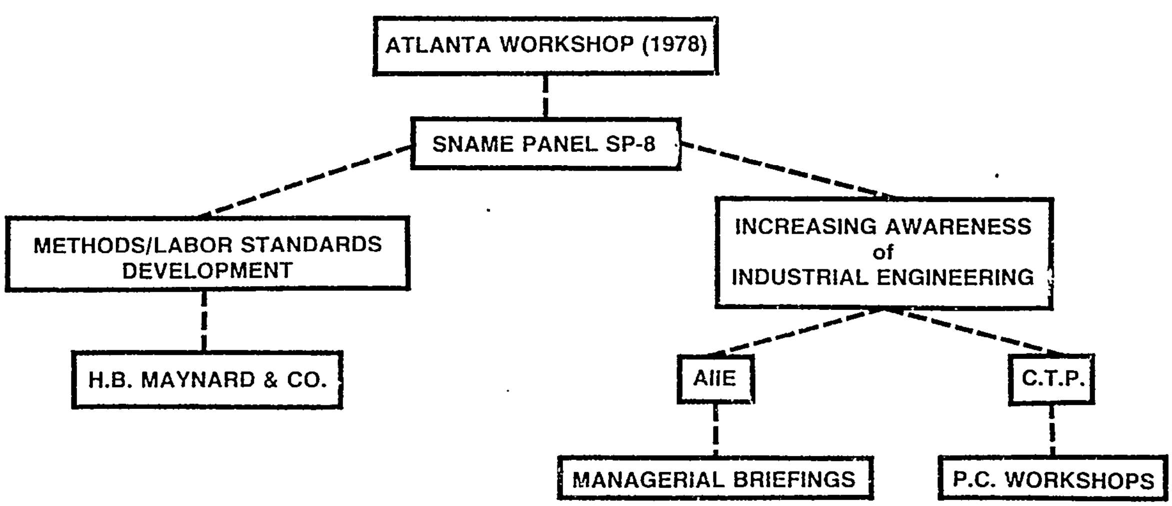
SHIP PRODUCIBILITY RESEARCH PROGRAM

STANDARDS & SPECIFICATIONS PANEL SP-6

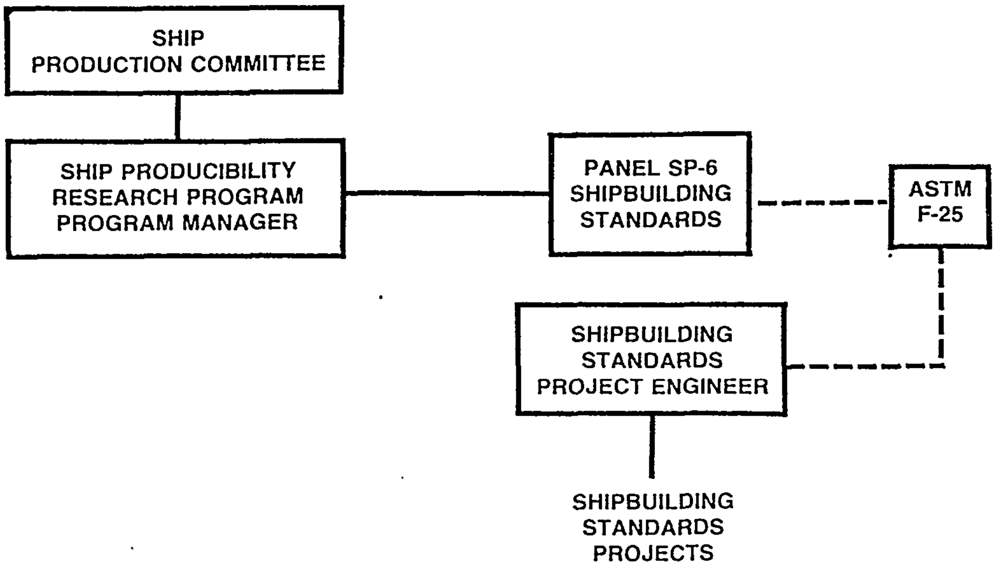


SHIP PRODUCIBILITY RESEARCH PROGRAM

INDUSTRIAL ENGINEERING PANEL SP-8



SHIP PRODUCIBILITY RESEARCH PROGRAM



SNAME PANEL SP-6

STANDARDS AND SPECIFICATIONS

SCOPE: *To act as the U.S. Shipbuilding Industry's steering committee for the National Shipbuilding Standards Program and to set shipyard plans and priorities for standard development, and thru the SNAME Ship Production Committee, recommend cooperative* MARAD/Industry cost-shared *projects which will* accelerate *direct benefits to the industry.*

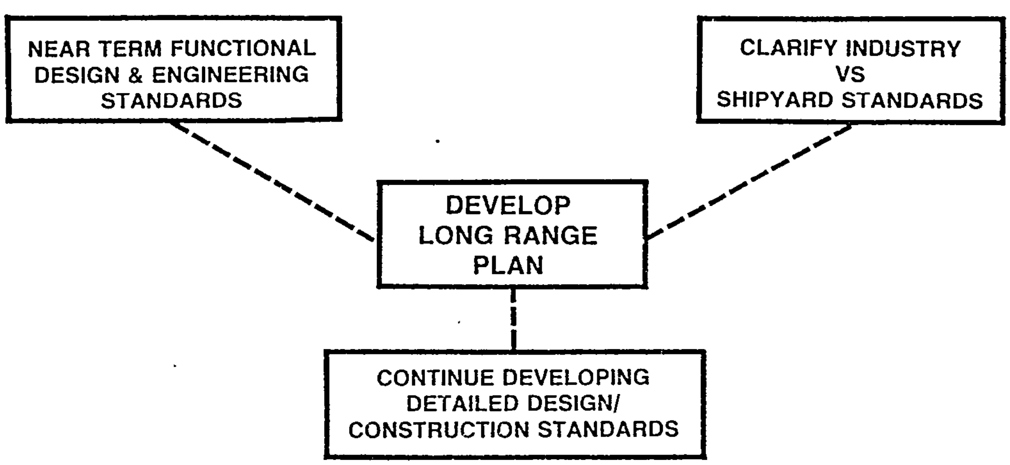
P A N E L   S P - 6   M E M B E R S H I P

AVONDALE SHIPYARDS
BATH IRON WORKS
BETHLEHEM STEEL
DAVIE SHIPBUILDING. LTD.
LEVINGSTON SHIPBUILDING
MARITIME ADMINISTRATION
NAVSEA
NASSCO
NEWPORT NEWS
SUNSHIP INC.
WILEY MFG.

PROSPECTIVE MEMBERS

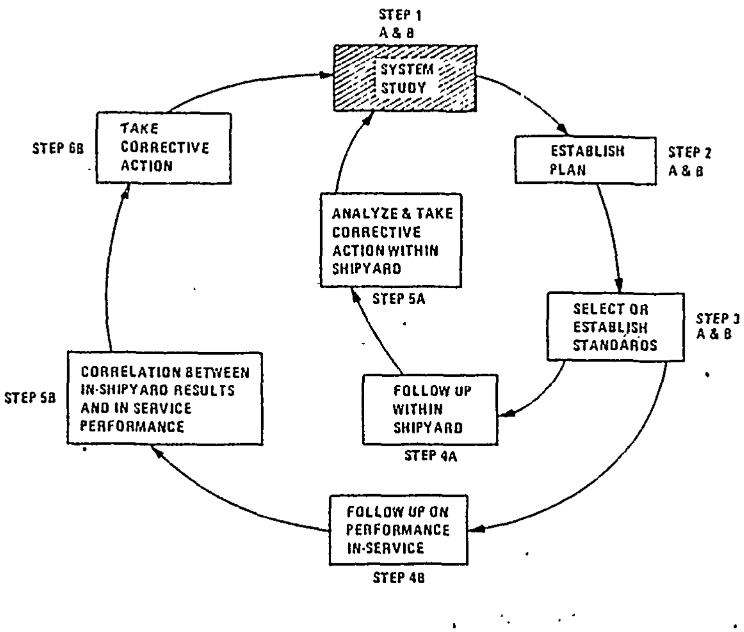
BAY SHIPBUILDING
MARINETTE MARINE
PETERSON BUILDERS
GD/QUINCY SHIPBUILDING DIV.
TACOMA BOAT BUILDING

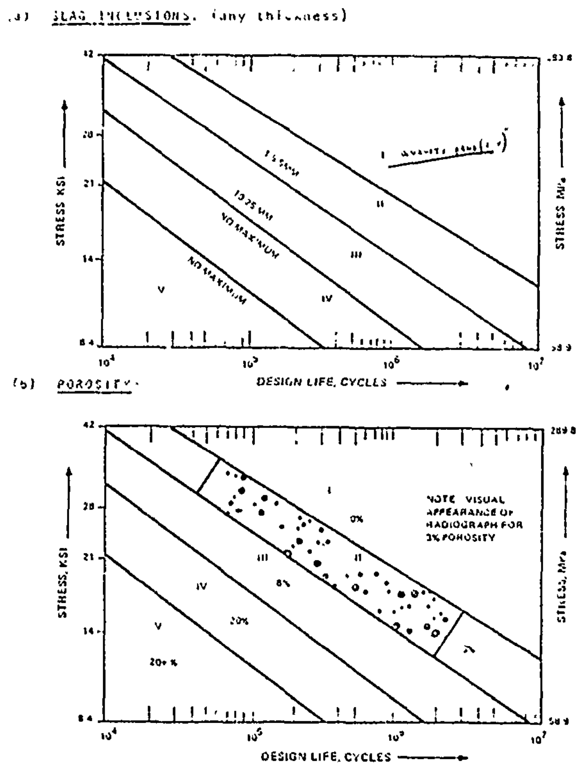
CURRENT SP-6 PRIORITIES



WELD DEFECT TOLERANCE STUDY

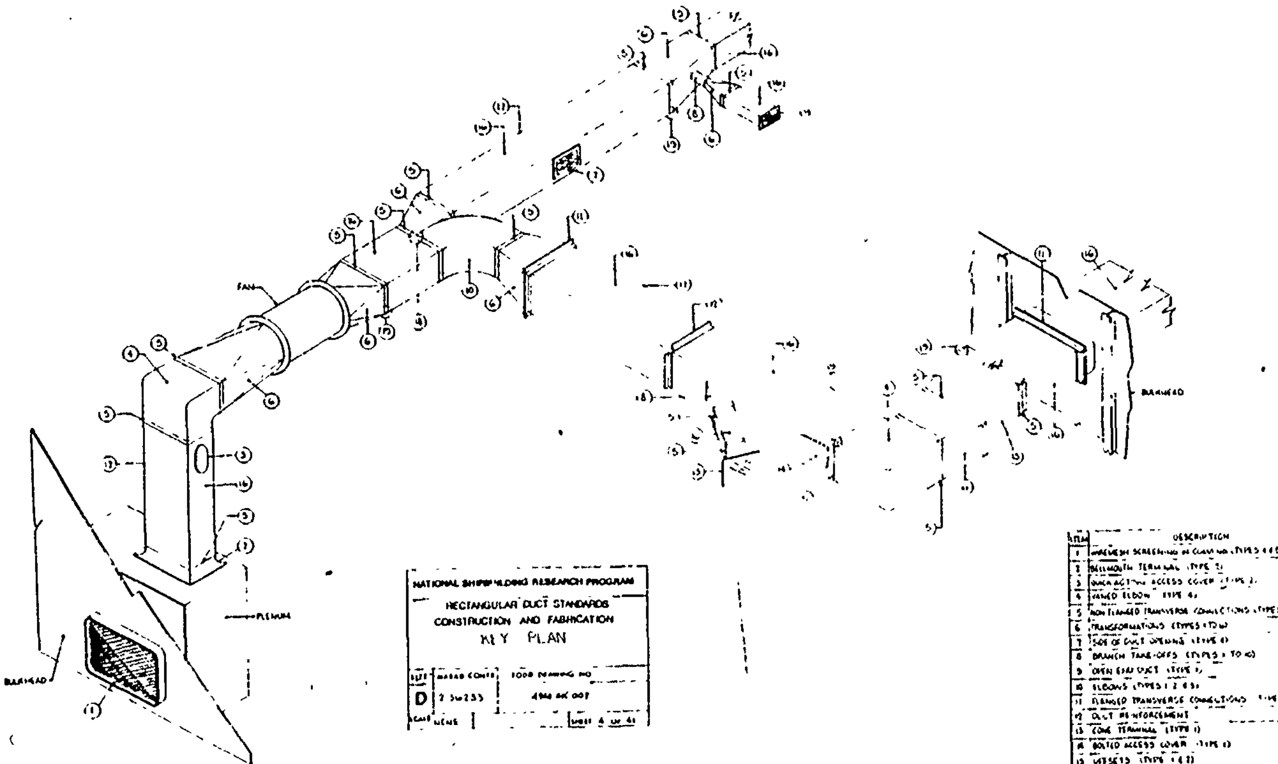
TASK S-22





SUN SHIPBUILDING INC.

HVAC DESIGN/CONSTRUCTION STANDARDS
TASK S-25



NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS
CONSTRUCTION AND FABRICATION
KEY PLAN

SIZE	NAVSEA CONT.	FOOD DRAWING NO.
D	[illegible]	[illegible]
SCALE: NONE		SHEET 4 OF 41

ITEM	DESCRIPTION	SHEET NO.
1	WIRE MESH SCREENING AT COAMING (TYPES 1 & 5)	34 35 36 38
2	BELLMOUTH TERMINAL (TYPE 1)	19 33 35 37
3	QUICK ACTING ACCESS COVER (TYPE 2)	31
4	VANED ELBOW (TYPE 4)	[illegible]
5	NON FLANGED TRANSVERSE CONNECTIONS (TYPES 8 TO [illegible])	[illegible]
6	TRANSFORMATIONS (TYPES 1 TO [illegible])	[illegible]
7	SIDE OF DUCT OPENING (TYPE 1)	34 35 37
8	BRANCH TAKE-OFFS (TYPES 1 TO 10)	17
9	OPEN END DUCT (TYPE 1)	33 35 37
10	ELBOWS (TYPES 1 2 & 3)	[illegible]
11	FLANGED TRANSVERSE CONNECTIONS (TYPES 1 TO 7)	[illegible]
12	DUCT REINFORCEMENT	39
13	CONE TERMINAL (TYPE 1)	[illegible]
14	BOLTED ACCESS COVER (TYPE 1)	30
15	OFFSETS (TYPES 1 & 2)	6 9
16	STRAIGHT DUCT	5
17	LONGITUDINAL SEAMS (TYPES 1 TO [illegible])	22
18	PREPARATION OF DUCT AT SPLITS	40
19	END OF DUCT PREPARATION	41

BATH IRON WORKS CORP.

STANDARD PIPING MATERIAL SCHEDULE
TASK S-28

U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION
WASHINGTON, D.C. 20235

MARITIME ADMINISTRATION

SCHEDULE FOR PIPES, JOINTS, VALVES FITTINGS AND SYMBOLS

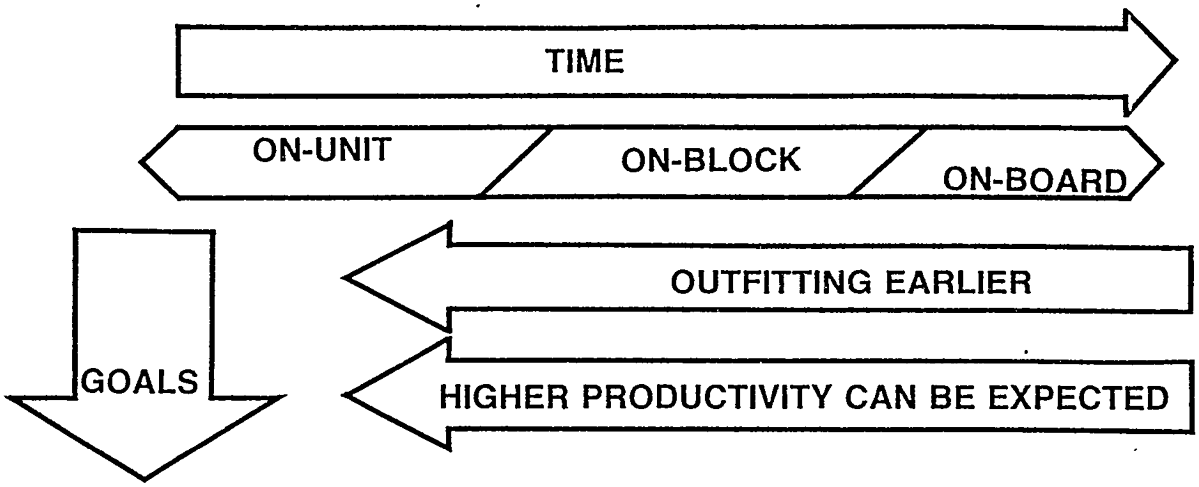
M.A. PLAN NO. S48-26-2, ALT. 3

NOVEMBER 1, 1957
Revised February 1, 1969

FOR OFFICIAL DISTRIBUTION

BATH IRON WORKS CORP.

ZONE OUTFITTING SUMMARY

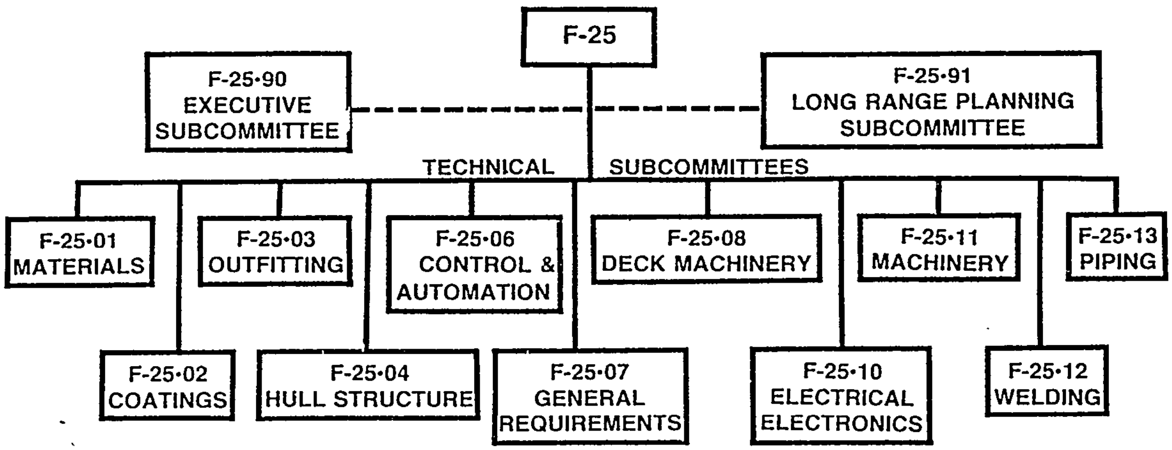


1) TO MINIMIZE WORK ON-BOARD (LOW EFFICIENCY WORK) AND TO INCREASE WORK IN SHOPS (HIGH EFFICIENCY WORK).
2) TO COMPLETE WORK ZONE-BY-ZONE IN ORDER TO SIMPLIFY MANAGEMENT CONTROL.
3) TO AVOID INTERFACE PROBLEMS WITH HULL CONSTRUCTION AND PAINTING AND THEIR ASSOCIATED WORK PROCESSES.
4) TO IMPROVE EFFICIENCY OF FACILITIES, SHOP, WAYS/DOCK, AND OUTFITTING PIERS BY EARLIER OUTFITTING AND MORE UNIFORM APPLICATION OF OUTFIT MANPOWER.

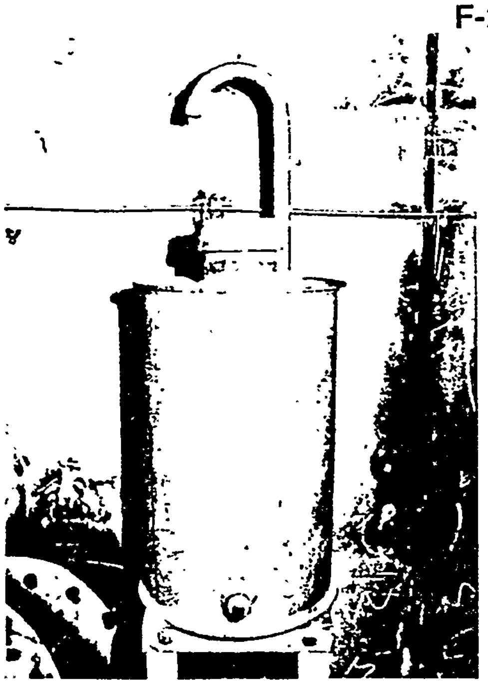
ASTM COMMITTEE F-25
SHIPBUILDING STANDARDS

SCOPE: *The scope of the Committee shall be to develop standard specifications, test methods, definitions, and practices for design construction, and repair of marine vessels. The committee will coordinate its efforts with other ASTM committees and outside organizations having mutual interest.*

COMMITTEE F-25 ORGANIZATION

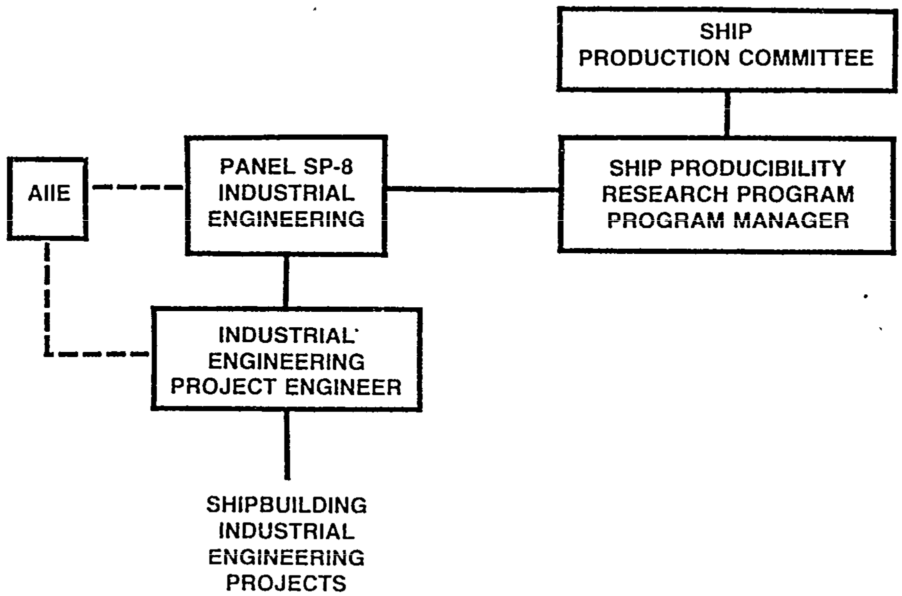


5 & 10 GAL. DISPENSING TANK
F-25•07


BEFORE


AFTER

SHIP PRODUCIBILITY RESEARCH PROGRAM



SNAME PANEL SP-8 INDUSTRIAL ENGINEERING

SCOPE: *To assist U.S. shipyards in the development and implementation of an improved industrial engineering capability.*

SP-8 PRIORITY ACTION ITEMS

(A) METHODS ENGINEERING/LABOR STANDARDS DEVELOPMENT

(B) INCREASE SHIPBUILDING MANAGEMENT AWARENESS OF THE SCOPE AND POTENTIAL OF BASIC INDUSTRIAL ENGINEERING TECHNIQUES IN SHIPBUILDING

AN INFORMATION SERVICE FOR THE MARITIME INDUSTRY

Davis G. Mellor
Manager
Maritime Research Information Service
National Academy of Sciences
Washington, D.C.

ABSTRACT

The paper reviews the services and publications available to the maritime industry through the Maritime Research Information Service (MRIS). This is a computer based service sponsored by the Maritime Administration and operated by the Transportation Research Board of the National Research Council. Information distribution to the maritime industry is provided. through monthly and semi-annual publications to subscribers, special bibliographies, computerized retrievals on request, and on-line retrieval directly through the Lockheed DIALOG System.

The Maritime Research Information Service (MRIS) has been in operation for over nine years. It is sponsored by the U.S. Maritime Administration and operated by the Transportation Research Board of the National Research Council for the benefit of the maritime industry. The purpose of the service is to provide rapid access to maritime information that has been brought together from numerous sources.

MRIS selects, abstracts, and stores maritime information that relates to the design, building and operation of commercial vessels. The information covers vessels that operate on inland waterways as well as in foreign commerce.

The MRIS data base now contains 20,000 abstracts of reports, journal articles and conference proceedings. Storage of this information in the computer at the National Research Council makes it possible to retrieve information on request, and to use the output to produce publications.

The sources of information for MRIS input consist of articles from the various maritime journals (U.S. and foreign), reports resulting from government sponsored research, conference proceedings, and papers from technical societies such as SNAME.

The maritime information in MRIS is from international as well as domestic sources. The major input of overseas maritime information is covered through exchange agreements with the British Ship Research Association, the Norwegian Ship Research Institute, and membership in foreign technical societies.

Basically MRIS provides information in four different ways. First - to subscribers through two publications:

> MRIS Abstracts is issued in June and December each year. Each issue covers all the information collected during each six month period and has two major divisions: abstracts of reports and journal papers, and summaries of ongoing research. The abstracts and summaries are grouped under 24 subject areas that are listed later in the paper. In addition, each issue of the Abstracts has a keyword index, a list of authors, and a list of publishers and performing or publishing agencies.
>
> Current Awareness Service is issued each month and contains abstracts of published reports and papers as well as summaries of ongoing research that were abstracted during the month. The format is the same as MRIS ABSTRACTS, but without indexes. In addition, each issue contains information on maritime meetings and conferences.

Second - on-request computer retrievals on specific topics. These generally are handled very simply by a telephone call to one of the MRIS maritime information specialists.

Third - U.S. and Canadian users can now search the MRIS data base via the Lockheed DIALOG on-line retrieval system. This new mode of access to maritime information makes it possible for users to search for information on specific questions and learn immediately of information that is contained in the data base. Applicable Abstracts can be displayed at the user's terminal or may be ordered through Lockheed's off-line printout service. Each abstract indicates where the user may acquire the corresponding report or article that is represented by the abstract.

Present U.S. and Canadian users of DIALOG data bases do not need to make additional arrangements with Lockheed to use the MRIS data base. U.S. and Canadian Organizations who are not present DIALOG users should communicate with Lockheed to receive an order form for on-line use and an information package that describes all DIALOG services and how to use them.* At present, there is no provision for use by overseas organizations.

Fourth - Special publications represent the last type of MRIS output. Generally these are bibliographies with abstracts. Four bibliographies of this type, already published, are Marine System in Frigid Environments, March 1978; Waterborn Transit, October 1978 and Maritime Information Sources: A Guide to Current Date, August 1979 and Dry Bulk Carriers, Cargos and Terminals, April 1980.

All information abstracted and stored in the data base is classified according to one of the following 24 categories:

01 Arctic and Cold Weather Operations
02 Air Conditioning, Heating and Refrigeration
03 Auxiliaries
04 Cargo and Materials Handling
05 Corrosion, Fouling and Protection
06 Electric Generation and Distribution
07 Experimental Ships and Special Type of Craft
08 Lubrication, Fuels and Combustion Technology
09 Management and Advanced Planning
10 Maritime Labor, Education and Training
11 Marketing and Traffic Management
12 Materials
13 Navigation, Communications, and Detection
14 Pollution Abatement and Control
15 Ports and Waterways

*Further information on Lockheed's DIALOG on-line retrieval system may be obtained from Customer Services, 3460 Hillview Ave.,Palo Alto, CA 94304. In the continental United States, the TOLL FREE number is (800) 227-1960, except Calizornia. California users may call TOLL FREE (800) 982-5838. A Customer Services representative may also be reached for direct assistance on (415) 493-4411 ext. 45412.

16 Propellers, Gear Trains, Shafting, and Couplings
17 Propulsion Machinery
18 Safety and Damage Control
19 Ship Construction, Conversion and Repair
20 Ship Design and Analyses
21 Ship Handling and Control Systems
22 Ship Operation
23 Strength of Materials and Structural Analysis
24 Trade Development and International Commerce

MRIS *is* one of four modally oriented transportation information services operated by the Transportation Research Board. The other three are the Highway (HRIS), Railroad (RRIS), and Air Transport (ATRIS) research information services. Since all four modes use the same software and computer, it is possible to provide multimodal retrievals when required by *a* requestor's need for transportation information.

There are additional sources of information that can be tapped only through voluntary cooperation. These consist of the many individuals, companies, state and local agencies who collect maritime information or produce reports in the maritime field. If these reports are forwarded to MRIS, on Loan for input, the service can provide greater indepth output for all users.

We believe that cooperation of this type by people seeking specific maritime information as well as the agencies that generate information, can only improve the quality and usefulness of the service.

For further information about MRIS, Write or Call:

MARITIME RESEARCH INFORMATION SERVICE
2101 Constitution Avenue, N.W.
Washington, D.C. 20418
Tel: (202) 389-6687 or 6452

A REPORT ON THE IPAD NATIONAL SYMPOSIUM

Douglas J. Martin
Group Leader, Shipbuilding Technology
IIT Research Institute
Chicago, Illinois

Mr. Martin is currently responsible for all REAPS program activities at IIT Research Institute (IITRI) and for computer aided design developments within IITRI.

He holds a degree in naval architecture and marine engineering from the University of Michigan. Mr. Martin has 8 years experience in the design and development of computer aided design systems primarily for ship design applications.

ABSTRACT

The Integrated Programs for Aerospace-Vehicle Design (IPAD) National Symposium was held September 17-19, 1980 in Denver, Colorado and was attended by some 420 people from the aerospace, computer, automotive and allied industries and agencies. The Symposium was sponsored by NASA and the IPAD Industry Technical Advisory Board.

In lieu of a summary of the presentations given at that conference, reproduced herein is the official IPAD Executive Summary, (Rev Sym A -- prepared under the auspices of Dr. Robert E. Fulton, IPAD Project Manager). A description of IPAD; its capabilities, perspective views by the engineering executive, manager, user and application programmer; and the IPAD development plan are presented.

Copies of the Proceedings of the IPAD National Symposium may be requested by writing:

IPAD Program Support Manager
MS 73-03, Orgn. G-5510
P.O. Box 24346
Seattle, Washington 98124

1.0 INTRODUCTION

The goal of IPAD is to increase U.S. aerospace industry productivity **through** the application of computers to **manage** engineering data in the 1980's. The system is being developed by The Boeing Company under contract to NASA. The system development is coordinated with the U.S. Air Force Integrated Computer-Aided Manufacturing (ICAM) and makes provision for interfacing design data **with** manufacturing organizations within a company, as well as with other companies. This document presents the purposes of IPAD, an overview of its capabilities, and how the system should be viewed by executives, managers, engineers, and programmers. It reflects IPAD as perceived at the software preliminary design stage and will be updated as IPAD development proceeds.

The purpose of the IPAD development is to define and implement an integrated computer software system to support planning, data definition, and control of an integrated engineering design process; storage definition and control of data bases containing large quantities of engineering data; and control and use of a large library of engineering application computer programs. Functional capabilities are provided and include: implementation of enhanced user interface features which support several levels of user skill; implementation of communication features which support distributed processing on several computing systems in wide use and implementation of state-of-the-art standard utilities for CAD and CAM in an integrated environment.

During the late **1960's** the use of computers for integration of design data evolved as a basic concept. In the early 1970's a NASA-funded feasibility study (ref. 1 and 2) showed **that** increases in individual productivity are feasible through automation and computer support of routine information handling. Such automation will directly decrease cost and flowtime in the product design process and will improve the competitive position of the U.S. aerospace industry. The industry was deeply involved during the IPAD feasibility studies and continues to be involved in the current IPAD development, A description of this involvement is given in Appendix A.

The IPAD development plan, which is open-ended and evolutionary, stems from requirements (ref. 98 and **19)** based on needed improvements in scientific data processing and from known potential improvements in engineering productivity (ref. 9 and 2). The development plan recognizes **that** IPAD is part of an environment composed of the IPAD system, users, technical application computer programs, **and data bases.** Thus the IPAD system is developed to be an intimate part of the total design environment.

2.0 IPAD DESCRIPTION

The IPAD system is a general purpose interactive computing system developed to support engineering design processes, Its primary function is to handle engineering data and management data associated with the design process. It is intended to support continuous design activities of a typical company mix of multiple development projects. IPAD serves management and engineering staffs at all levels of design (conceptual, preliminary, and final) and aids in the assembly and organization of design data for manufacturing processes.

The IPAD system design will support generation, storage and management of large quantities of data. Its capacity will only be limited by the hardware configurations selected by each company. The system is intended for use in a distributed computing environment having one or more central host computing systems and many remote computing systems. The number of terminals supported may range to several hundred and may be distributed across the host and remote systems. The IPAD software will function on the "third generation" computer complexes in use today by large aerospace corporations.

Figure 2.0-1 illustrates the relationship or the major software elements of IPAD. It is currently visualized as composed of four major software elements: **1)** executive software to control user-directed processes through "interactive" interfaces with a large number of terminals in simultaneous use by engineering and management personnel and to provide communications between computer hardware within the IPAD distributed computing system; 2) a large number of utility software packages for routine information manipulation and display functions; 3) data management software (information processor) to provide a comprehensive, versatile capability for efficiently storing, tracking, protecting, and retrieving exceptionally large quantities of data maintained on multiple storage devices and 4) other systems interface software to provide communications to computing systems outside of IPAD.

Libraries within the data bases include the technical analysis and design computer programs utilized by various disciplinary specialists. Such programs are not part of IPAD, but must be provided by each company to form the complete design-software system. Some public technical programs will be included with the IPAD system to demonstrate its capabilities. The data base will include all official project information defining the characteristics of current baselines and alternative designs and their performance, as well as archival 'handbook" information forming the technology base for company designs. Simultaneous access to the same baeline design information by all disciplinary

groups will thus be possible. Temporary storage, for design information being **actively used by individuals or teams, will also** be provided

IPAD Software Elements Augment Host Operating Systems

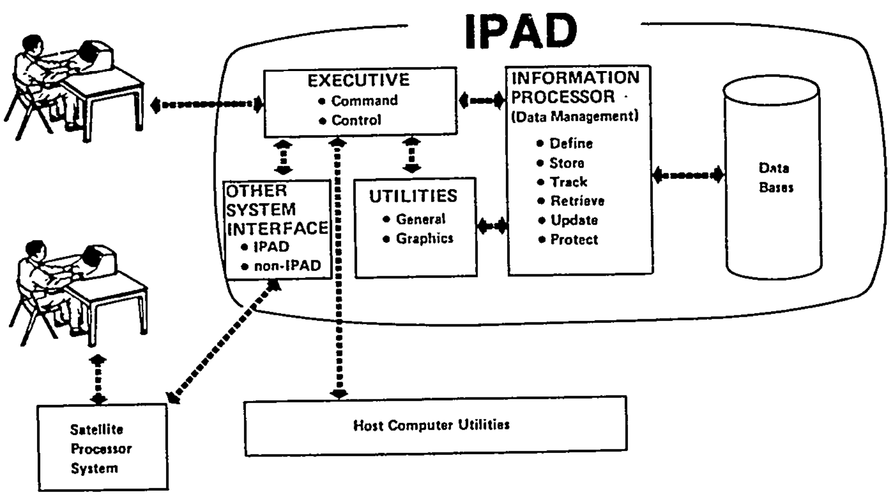


Figure 2.0-1 Primary IPAD Software Elements

IPAD is not a hands off "automated design" system and will not constrain company design methods. The **characteristics and** quality of aerospace designs in the future, **as now, will** depend on such elements as creativity of designers, quality of technical staffs and their analysis tools and **design** data, and coordination or design and manufacturing information. IPAD is a tool to improve the efficiency and effectiveness of these elements and to provide manufacturing direct access to engineering data. The manufacturing process **is** not encompassed by the IPAD system. However, there is a working agreement between the Air Force and NASA to insure compatibility between IPAD and ICAM. This capability will enable manufacturing users to take advantage of the design and data management features of IPAD in addition to accessing design information.

The IPAD system and its supporting documentation will be supplied to aerospace companies. IPAD may be installed by each company on its computers and used in a manner similar to the operating systems supplied with each computer. It will augment rather than replace the existing operating system. The IPAD system development plan provides for release of incremental capabilities implemented for CDC and IBM computing systems and allows a gradual transition from the current computing techniques to IPAD integrated techniques at a pace selected by each company for its own Implementation schedule.

While IPAD is developed for use by the aerospace industry, **it** should support other complex processes such as large **civil** engineering projects, ship building. automotive design and the development of other computing systems. (See ref. 13 for examples of potential non-aerospace applications of IPAD.)

3.0 IPAD CAPABILITIES AND DOCUMENTATION

This section contains a brief description of the capabilities of the IPAD system and the documentation to be provided along with the IPAD system.

The IPAD system capabilities are:

a) Manage data by means of a single-source, bank of current **and** historic information accessible to all users. Such a bank enables management to control and use data as a company resource and thus improve all of its operations by ensuring that all organizations have common access to a uniform information source which is continuously updated and purgea of obsolete, redundant, or conflicting data.

b) Provide computer aided planning of engineering design processes by a modeling method that makes it convenient to describe the design process as groups of related activities. This planning includes definition of computer based data interfaces which enable integrated information processing. These design activities may be time-phased as required to develop the technical definition of a product.

c) Support computer aided design project management with the capability for defining design projects; assigning manpower, resources and schedule for tasks and subtasks; and for monitoring progress of design projects relative to resources and schedule.

d) Support an open-ended computer program library of user-installed application programs in source and executable forms. One or more of these programs may be executed as an IPAD job. Each IPAD job will have sufficient library information installed with it to describe adequately the job's purpose and capabilities (abstract, key words, etc.). This information is available to anyone performing a function associated with the job and is used to plan and define process activities based on available IPAD jobs. This program library should minimize program redundancies.

e) Enable users to interface effectively with the IPAD system by providing:

   Fast, convenient access to the system and identification of individual users for security and control purposes

- User-oriented, **functional command language which** guides the users control of the IPAD system

- System prompting when users need online help. (Several skill levels are accommodated, such as expert, intermediate, and novice.)

- Computer-aided instruction in the use of IPAD functions (this instructional system can also be used to train engineers in design procedures, use of computing tools, etc.)

- Aid in locating input data, executing jobs, monitoring jobs in execution, and storing output data

- Job status reports showing progress of the job and resources used

- Aid to users in suspending jobs **in** execution and resuming execution under user control with minimum effort at a later **time**

- 'Aid to construct **jobs** from **application** programs in the IPAD program library

- Aid to define data

f) Provide essential functional utilities including:

- State-or-the-art graphics and interactive graphical capabilities for design drafting and finite element modeling

- State-of-the-art programming aids for on-line programming, program maintenance, and installation of existing programs into the program library

- Miscellaneous aids such as tutorial, text editing, menu building, report generation, and message processing

Documentation provided with the IPAD software include:

- A reference design process (ref. 16) the interaction with manufacturing (ref. **17)** and product program management systems (ref. 20). These serve as aids for each company's use in producing its unique version of the design process, information bank, and application program library

A software standards handbook to ensure **consistent** techniques for the IPAD system development and maintenance

IPAD user manual to provide **reference material on** IPAD functional capabilities

IPAD software workbooks to provide instructions on installation and maintenance of IPAD software

4.0 ENGINEERING EXECUTIVE'S (INDUSTRY) VIEW OF IPAD

IPAD might be viewed by industry as an advanced computing system for processing engineering data, The following are major considerations of the engineering executive's perception of IPAD.

4.1 EFFICIENCY

IPAD wi11 provide the capability to increase productivity of a product design organization by providing tools for handling information. Examples of the reductions possible in one area of preliminary design (see Ref. 1, Vol. 7 for more detail) are illustrated by figures **4.1-l** and 4.1-2. These figures show flowtime and manhours required for one airplane configuration sizing design cycle in a stand alone environment and an integrated environment with data interfaces defined. The estimated reduction for the integrated environment are summarized as follows:

Flowtime is reduced to 30%

Man-weeks are reduced to 20%

4.2 COMMUNICATIONS

The IPAD interfaces with other systems will support communication between the computing systems within engineering and the computing systems of Other functional organizations.

The IPAD data management capabilities will handle both business and scientific data types. These capabilities will support communications within engineering and between engineering and other organizations,

Figure 4.2-l illustrates some of the engineering data types that may be stored and communicated with IPAD. Many organizations currently use commercial data **base** management systems (DBMS) to store and communicate engineering business type data such as release of engineering parts. Examples of business data are: part names, part numbers , part quantities, etc. Data of this type have characteristics and relationships that are easily communicated to people. In contrast engineering scientific type data are more complex and include elements such as coefficients of a polynomial expression and the geometric **data** defining the surface of an aircraft, These data have complex mathematical relationships and are handled by IPAD **through** an enhancement of current commercial data base technology to include both scientific and business data types in one integrated system.

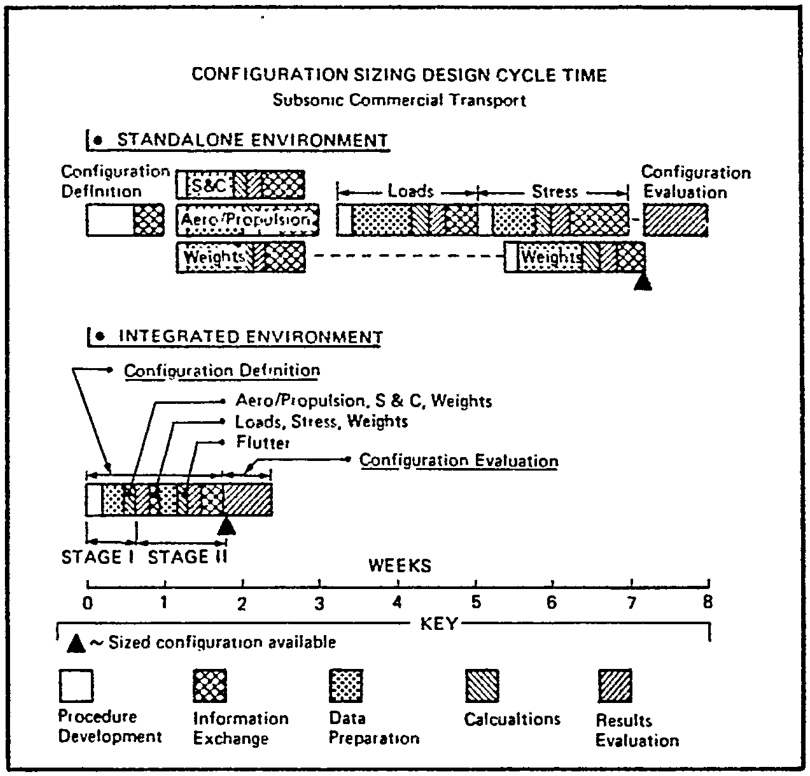


Figure 4.1-1 — Subsonic Transport, Relative FLowtime, Standalone/Integrated Enviornment

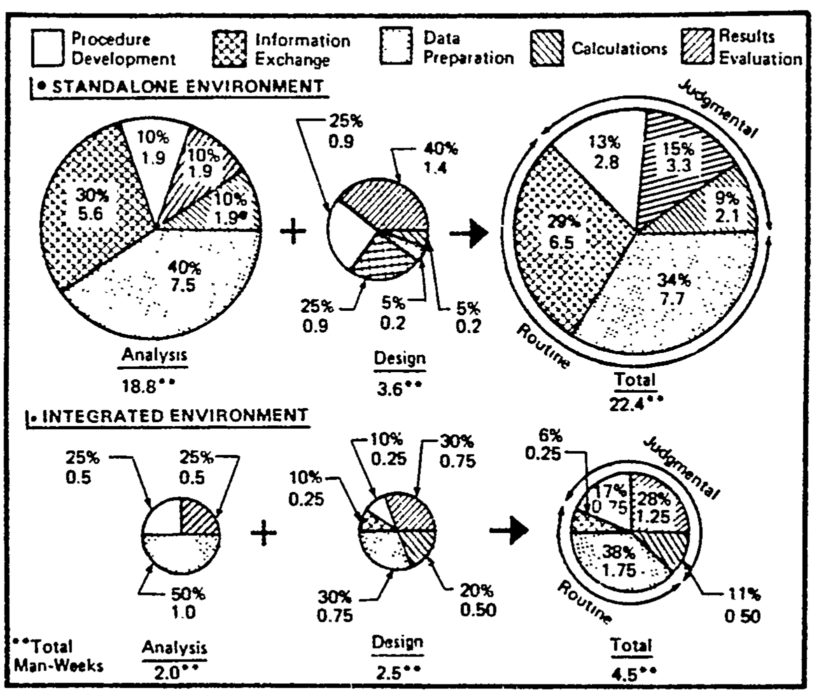


Figure 4.1-2 — Subsonic Transport, Division of Effort Standalone/Integrated Enviornment

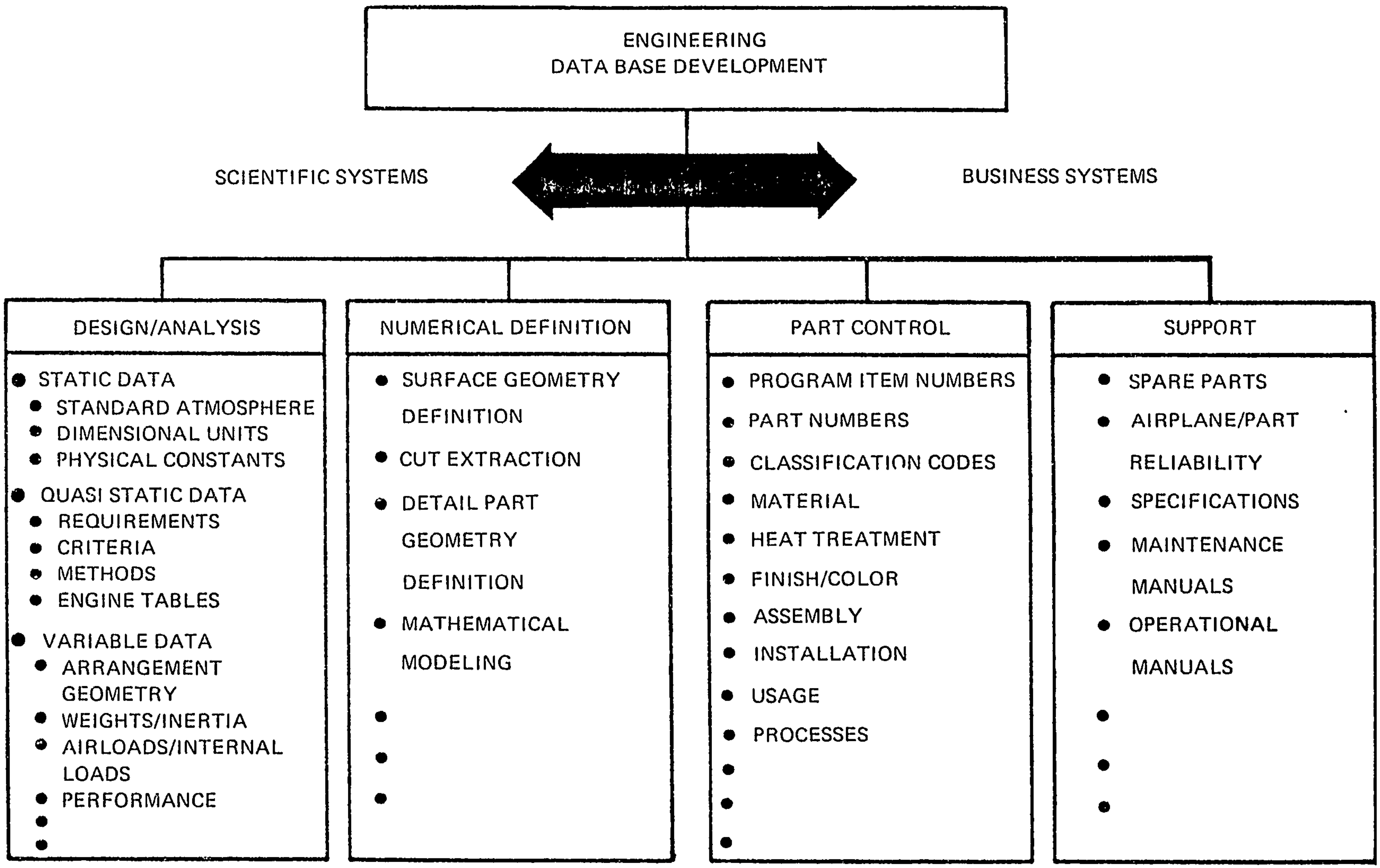


Figure 4.2- 1. - Engineering Data Types

Data interfaces within engineering are developed with the IPAD capability to plan design processes and define integrated data interfaces. These processes can be related to one another in a way that will cover the development cycle of a product from conceptual design through product certification and support. To maximize the benefits of IPAD, a coordinated effort is required on the part of engineering managers, group supervisors and methods **research.** The experience and quality of the personnel assigned to plan the process and define the required data interfaces will determine the effectiveness of the use of IPAD,

The IPAD capability to support definition of data interfaces can also be applied to the interfaces among engineering and other functional departments of a company, such as finance, marketing, and manufacturing. This can be accomplished through a coordinated effort initiated by department executives to utilize the capabilities of IPAD to plan and **implements** desired data **communication among their respective organizations.**

4.3 APPROACH TO IPAD IMPLEMENTATION

The IPAD system is developed in the public domain and is available to the U.S. Industry. Incorporation of IPAD by a company may be planned as a transition, beginning with a small initial implementation for specific portions of the design process. This initial implementation can be built upon and expanded until all elements of the design process and its interfaces have been integrated. In this manner a company may implement IPAD at its own pace consistent with the benefits desired.

The cost of involvement in IPAD activities will be a function of how deeply each company elects to become involved and will remain under company control. A comprehensive approach for initial implementation and evaluation of IPAD could include the following tasks:

a) Identity a team of specialists in each engineering discipline from ongoing design and analysis projects, methods research and the computing staff

b) Review the reference design process model (D6-IPAD-70010-D), manufacturing interactions with the design proess (D6-IPAD-70011-D), and product program management systems (D6-IPAD-70035-D)

c) Assess the applicability of the reference material to comparable functions within the company

d) Select portions of the design process to be implemented and adapt the IPAD design process model to fit in-house procedures and standards

e) Develop cost estimates and a schedule for initial implementation based on step d

f) Initiate the IPAD program library by modifying existing application programs and developing new ones for effective integration based on the in-house IPAD design process models

g) Initiate implementation of the IPAD information bank based on the data definition extracted from the in-house IPAD design process models

h) Implement computer hardware/software configurations required

i) Establish in-house procedures for maintenance of the IPAD system

j) Utilize the computer aided instruction within IPAD to train engineering users

k) Consider participating with other IPAD users to guide and shape continued development of IPAD

The cost of carrying out these tasks will depend on how comprehensive an activity is needed and how much has already been done. Steps b, c, d, and e could involve as much as 5 to 10 man years over a period of 4-12 months. Steps f, g, h, and i constitute initial implementation and the costs should be identified in step e. The conversion and installation of applicable computer programs and data into IPAD will be an ongoing process based on cost benefits. If possible, companies should consider a limited IPAD implementation for evaluation purposes in parallel with IPAD software development. Computer programs being developed or converted could be impacted by IPAD development issues and, similarily, the IPAD development itself could be influenced by the needs of such programs.

5.0 ENGINEERING MANAGER'S VIEW OF IPAD

IPAD might be viewed by an engineering manager as **1)** a means to develop design processes which incorporate engineering computing tools and interface those tools based on data relationships, and 2) a means to plan and monitor the progress of design projects including schedules, resources and manpower assignments. Sample capabilities are described in this section.

5.1 DESIGN PROCESS SUPPORT

Design process networks are constructed with IPAD to integrate engineering activities and interface engineering data within engineering disciplines and between engineering disciplines. The basic building blocks for process definition are computer programs in the IPAD computer program library. These programs are the computing tools used by engineering and are executed as jobs. Jobs may be grouped and groups of jobs grouped to any level required to stage or phase the design process and to support forward and feedback communications.

Figure 5.1-l illustrates an overview of the design levels which were used in reference 16 to describe the technical activities of the IPAD reference aerospace design process. Each level is further defined by one or more design networks of the type shown for IPAD level 11. This network establishes the Interfaces between engineering, marketing and finance and can be used to develop the design criteria for potential products.

IPAD will support displays of these process definitions and assist the engineer in the preparation for execution of the jobs required to accomplish activities identified in the process description. Engineers are assigned to accomplish these activities in accordance with the project plans described in 5.2.

5.2 DESIGN PROJECT MANAGEMENT

Computer aided design project management is provided by IPAD. Design projects are defined to control the execution of a complete process or any segmented portion of a process. The primary elements supported by IPAD are project planning and project records.

Tasks and subtasks are identified in a project plan. Each task is scheduled and resources allocated in the plan. Each subtask is scheduled and resources allocated in a task plan. A critical path may be constructed by defining dependencies of both **tasks** and subtasks. Tasks identify the work to be accomplished by engineering groups and subtasks **describe** the work activities to be

Level II

Design Levels — Design Criteria Selection

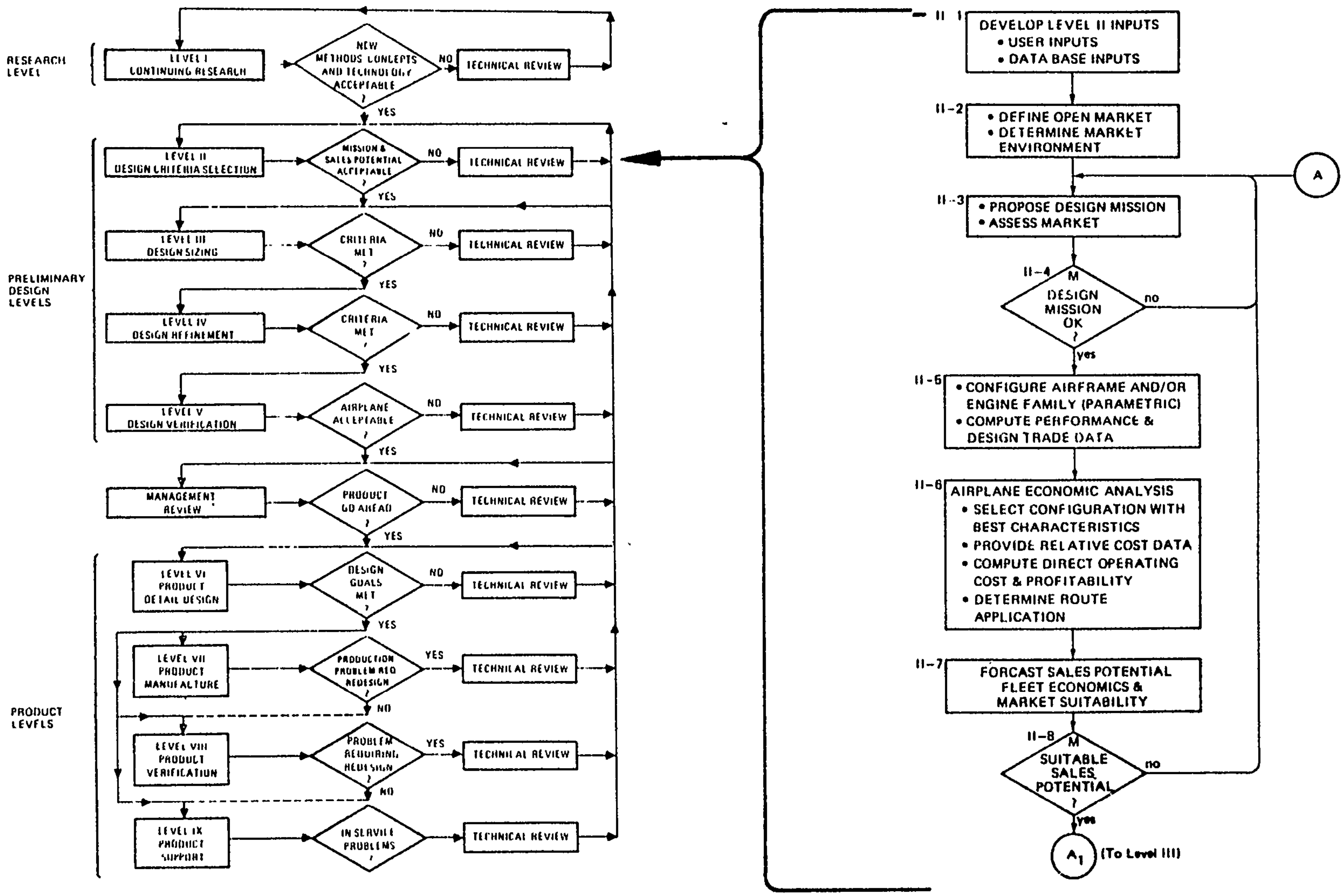


Figure 5.1–1. Reference Design Networks

accomplished by individual engineers. Each subtask may require execution of one or more jobs or IPAD utilities.

Project records are used as the primary means to identify the source and quality of all data generated and used by a project. These records are appended by IPAD to the data stored in the information bank.

IPAD will support interactive displays and automated pre-formatted displays of project records from the information bank. This will provide management with the capability to review plans, and schedules, make planned versus actual comparisons and track costs, such as development , production estimates, product support and product operation.

The engineering manager's decisions are based on known confidence in the data produced by a project. The known confidence stems from the process tools used and the planned quality of the input data used. These factors support risk evaluation by engineering managers of the technical definition of the product. The reduced time and resources for a design cycle permit the manager, based on known risk, to iterate these cycles until confidence in the quality and consistency of data is adequately established.

5.3 PERFORMANCE

Reduction of costs and schedules for design cycles were discussed in section **4.1.** Managers can apply these improvements in costs and schedules to all applicable areas of their operation using a transitional implementation of the integrated information processing technology supported by IPAD. The reduction of routine data preparation by interfacing jobs with data stored in the IPAD information bank will shift the level of effort from routine to judgmental activities thus improving the quality of the solution. In addition, the number of job failures caused by errors in input data will be recuced. These factors will contribute to improved performance of each engineering unit.

6.0 ENGINEER'S VIEW OF IPAD

IPAD might be viewed by an engineer as an advanced interactive computing system tailored to the enginering users needs. These needs range from the random gathering of information to control of the execution of complex programs in the application program library and IPAD system standard utility library.

6.1 DATA BASE SUPPORT

IPAD provides capabilities to store, retrieve and maintain engineering data, The IPAD information bank is a repository for historic data and data on current products and future products under development. Data maintenance provisions include version identification and the capability to track the differences between versions.

IPAD assists engineers in identifying and retrieving information. The engineer can request data by name or browse through the contents of the information bank by specific disciplines such as configuration design, wing design, loads, stress, hydraulic system, etc., or by key words such as wing aspect ratio, engine bypass ratio, cruise mach number, part number, etc. Ready access to engineering information is an important advantage for engineers, especially detail designers, and reduces the time to gather the information required to get ready for design work.

6.2 IPAD APPLICATION PROGRAM LIBRARY

IPAD provides the engineering user with access to a company-wide application program library. These application programs are readily available for execution as jobs which are the state-of-the-art tools developed by each company to apply technology to its product lines. The engineer can request jobs by name or browse through the library by specific technology and by key words. This ready access to tools should enhance the engineer's technical capability and reduce duplicate development of programs.

6.3 IPAD SYSTEM STANDARD UTILITY LIBRARY

IPAD provides the engineering designer with a set of standard utility programs which are state--of-the-art capabilities in such areas as graphics, design drafting, and finite element modeling. These utilities are supported by the IPAD system in a manner that provides a unified CAD/CAM capability in which a design may be created, analyzed, and released to the applicable manufacturing process within an integrated design environment. The geometry is

stored in an IPAD standard geometry format and easily communicated among CAD/CAM applications and to the applicable manufacturing systems.

6.4 WORK ENVIRONMENT

The engineer will work in an environment in which computing tools are readily available and structured to accommodate various user skills. Help is available on line and the engineer may easily terminate a session and resume at a later time. Most data bookkeeping is done automatically by the system, which can trace the origin of any data set.

In the areas of creative design for which integrated processes may not be defined, the design drafting capability of the standard CAD/CAM utility will enable the user to construct, modify, display, and manipulate geometric definitions. These geometry definitions are used by manufacturing to support functions, such as tool path definitions. Figure 6.4-1 illustrates typical hardware supported by IPAD at a computer aided design work station. Menus may be displayed on the graphics terminal or on a slave text terminal as illustrated. Menu selection may be implemented with function buttons, with light pens or using a data tablet with a menu overlay. The system can access the product loft definition for both cut and surface extractions needed for detail parts. Retrieval may be accomplished rapidly in an interactive mode using a language comfortable to the user, such as:

"DISPLAY REAR VIEW WHERE BODY STATION = 960"

Computer program execution within IPAD is based on pre-defined job control and many data interfaces with the information bank can also be pre-defined. The user identifies the job to be executed and the project and subtask names. IPAD links the job to applicable existing input data sets based on the project name and the process data interface definition. The user inputs the required additional data and initiates interactive execution or submits the job for batch processing. In either case, IPAD will automatically store the user-supplied input and the output produced in a temporary private data storage area identified by the user's subtask name. The user may access the data by the subtask name and data set name. Computer-aided features for data validation such as set comparison and range checks will assist the user in evaluating the results. This improved data communication will reduce the time engineers spend on routine data preparation and result in increased time spent on judgmental activities.

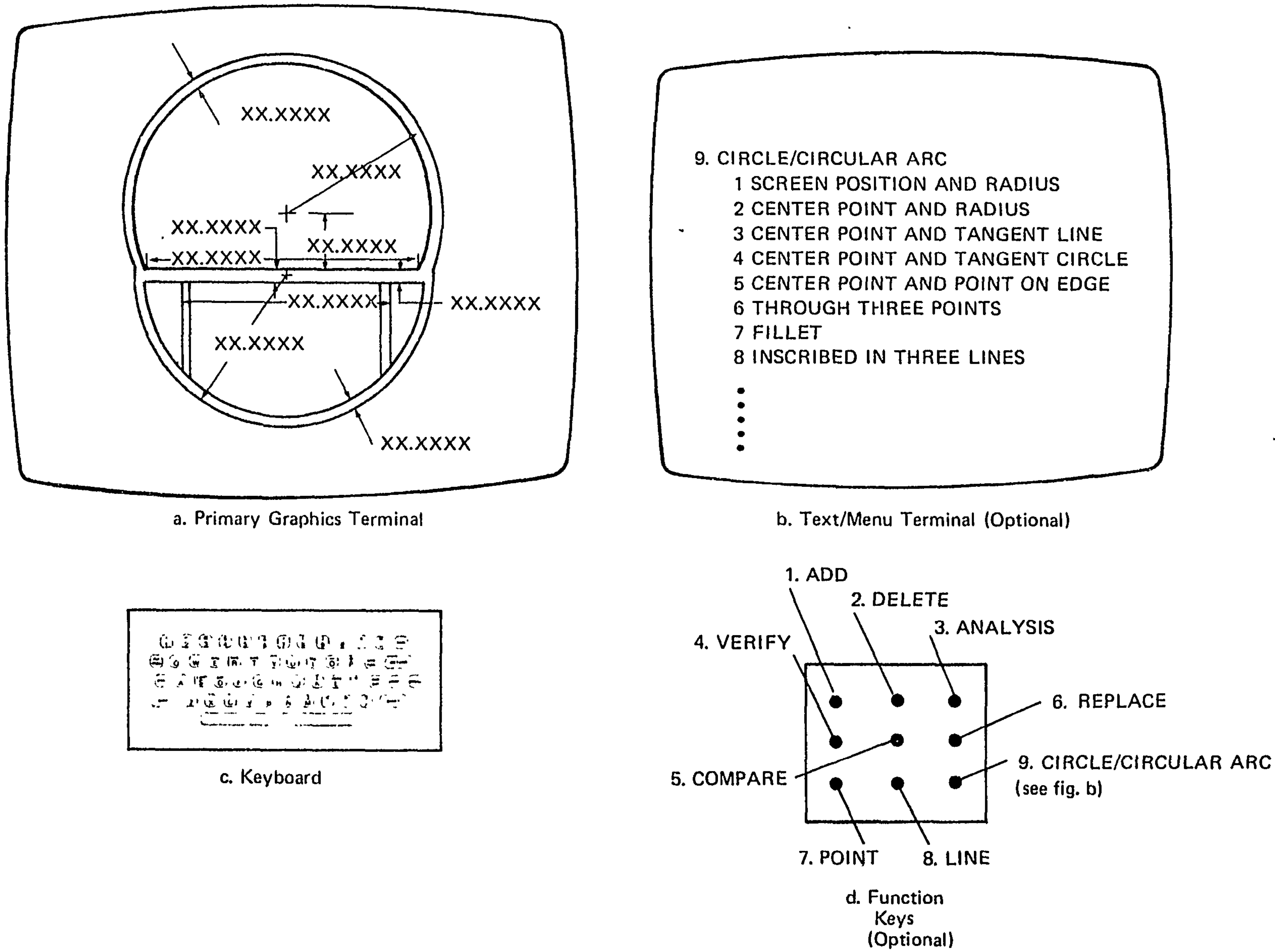


Figure 6.4- 1. - Typical Equipment - CAD work station

The system will provide the capability for a user to manage use of computing resources such as central processor time. If resource limits are exceeded, the system will automatically suspend execution and package the completed results in a manner suitable for restart with minimum loss. The user may examine the results completed and **resume** execution. Status reports are available to each user for all subtasks in work. The status reports include such items as:

Subtask schedules

Computer resources budget/used/remaining by subtask

Jobs completed by subtask

Resources for each job

Jobs suspended and probable cause of suspension

Resources used for results completed prior to job suspension

Data sets created

Data sets due

IPAD provides a data release procedure equivalent to signing a drawing and may include categories such as prepared, checked, and approved. When the user is satisfied with the output, an appropriate entry is made by the user. After persons designated have checked and approved the data and made appropriate entries, the data is **transferred** logically by IPAD from temporary storage to permanent storage area and is accessible as released Information. This relieves the engineering user from the burden of tracking data.

6.5 COMMUNICATIONS

Many features of the IPAD system will support both on-line and off-line communication between engineers. The terminal conference data viewing mode supports multiple terminals with common text and graphical displays. It will be possible to send messages on the screen and edit screen content from any of the terminals. Other online support includes review of process description and data interfaces. Offline output includes check print quality hard copies or complete drawings or screen content for coordination purposes prior to completion or release.

7.0 ENGINEERING APPLICATION PROGRAMMER'S VIEW OF IPAD

IPAD might be viewed by an engineering application programmer as a means to handle scientific data using a data base management system and to control application programs in a library environment similar to operating system and run time libraries thus simplifying use by the engineers.

7.1 PROGRAM DEVELOPMENT AND INSTALLATION

IPAD will support a large library of application programs and will provide the application programmer with a set of programming aids and standards.

Programs developed within IPAD or suitable existing programs may be installed in the IPAD program library which will support management of modules. Application programs must conform to an IPAD installation standard and will be installed as one or more operational modules, **A** job is use of a selected set of operational modules and/or other jobs executed by the user as part of a subtask. Any set of source code used several times will be entered once as a source language module and made available to the user community. The same applies to operational modules and jobs. Naming conventions result in unique names for all modules and jobs in the program library and are used as primary keys for program management. The construction of jobs from modules and the administrative information supported by IPAD is illustrated by figure 7.1-Y.

Programming aids are provided to support creation and maintenance of application programs and include on-line utilities for program text editing, debugging and update. In addition, host operating system programming aids may be accessed and used in conjunction with IPAD.

7.2 PROGRAM INTEGRATION

Program integration into IPAD involves linking programs as IPAD jobs to the data within the information bank and to other IPAD jobs as determined by its use within the design process,

Data formats must be defined for each input and output data set associated with a job. Two types of formats are provided. The first is for undefined data sets where IPAD manages data at the level of sets and does not know the contents of the set. The second is for defined data sets where data elements within a set and relationships between elements (i.e., structure of the data set) are defined and IPAD manages data at the level of elements,

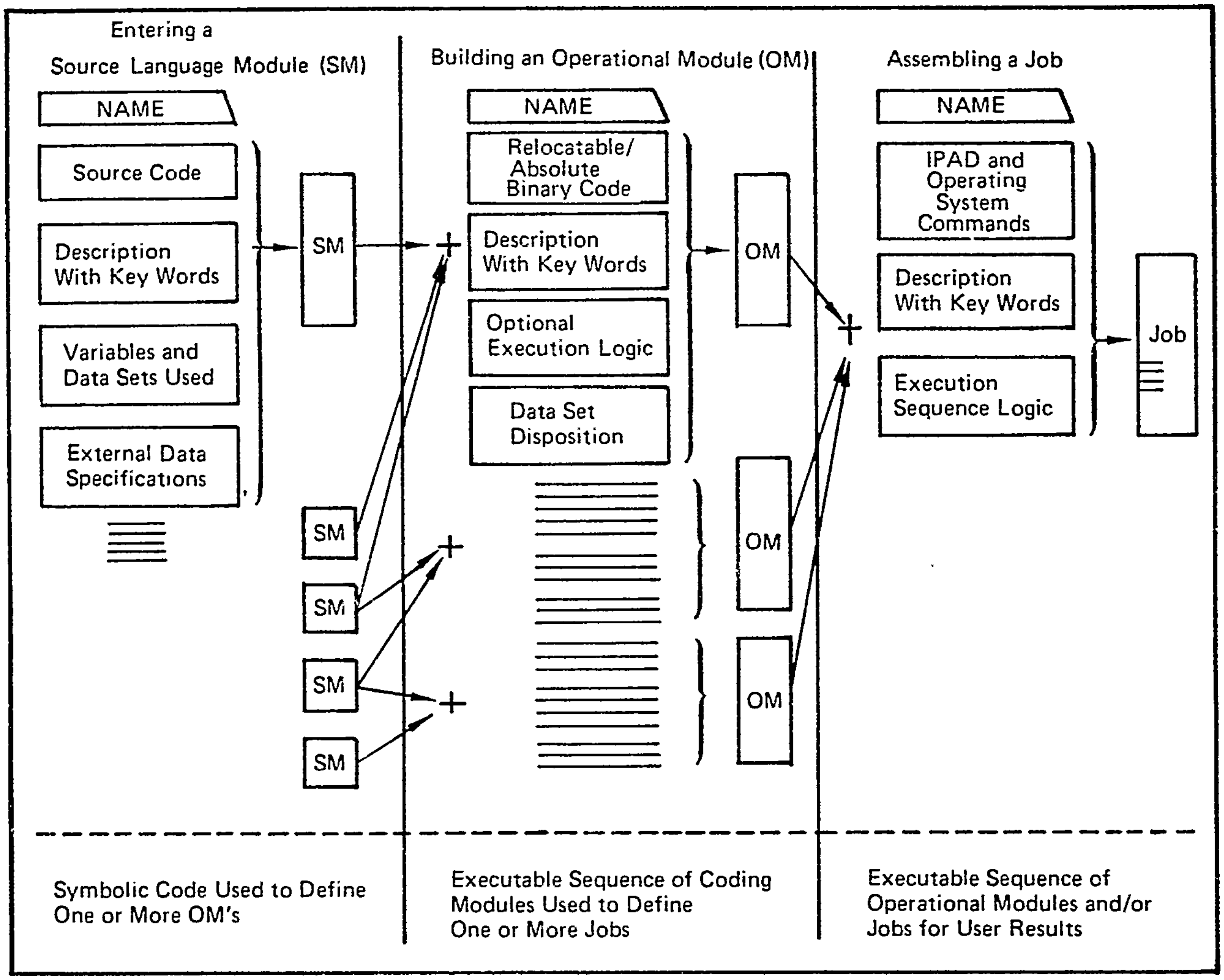


Figure 7.1-1 — Steps in Job Construction

A data modeling capability is used to establish definition of data flow within the design process. This definition identifies the source and destination of all input/output and makes provisions for job to job communication. Any required data reformatting or translation is identified by this data flow definition. Both forward and feedback data flow paths are supported. The source and destination definition are used to map storage and retrieval data flow between the process and the information bank and between related activities defined in the process.

7.3 PROGRAM MAINTENANCE

In addition to the programming aids mentioned in 7.1, the IPAD program library makes provision for version identification of modules and jobs **and** to track the difference between versions. The IPAD system itself is written in a high level system implementation language and has extensive system documentation. Sufficient information is provided to allow modification and enhancements to the IPAD system by individual companies choosing to tailor their IPAD installation.

8.0 IPAD DEVELOPMENT PLAN

The IPAD development is composed of two major steps.

1. Preparation of specifications and preliminary design of an IPAD system which will meet aerospace company design needs of the 1980's (ret. 16-21).

2. Design, code, document, test, and release a "First-Level" IPAD system, a truncated working version of IPAD, which encompasses the critical features and is extendable to a full IPAD system.

These steps are covered by the current development contract. Following development, it is NASA's intent (ref. 15) to turn over responsibility for IPAD maintenance and improvement to industry after an initial maintenance period of undetermined duration in which NASA and industry will share the responsibility. The exact mechanisms for cost sharing and the transfer will be worked out with industry before the end of the current development **contract.**

The first step developed specifications and preliminary design of the IPAD system based on functional and software requirements provided by NASA, as refined and expanded by the development contractor. Use has been made, where appropriate, of references 1 and 2. The IPAD functional **requirements include** support of the design process at all levels for long periods of time; information processing; technical computer program assembly, integration, and execution; sequencing of design tasks; and display of graphical and alphanumeric information. The interactive computer terminal is the primary interface between IPAD users and the system. The design of IPAD software builds on existing computer-aided design technology and uses new concepts in computer science where the need is critical. St will support today's design processes **and** permit development of **new design** methods for the future.

The second step develops First-Level IPAD from the IPAD preliminary design and meets minimum requirements specified by NASA. High levels of system reliability, maintainability, and portability are key characteristics of First-Level IPAD. First-Level IPAD includes incremental releases of selected software for testing by industry at regular intervals. The precise nature of software releases is determined during the development process. All First-Level IPAD software is developed for two time-shared computer complexes (CDC CYBER 172, and IBM 370) to demonstrate portability requirements which minimize machine dependency. A subcontract will be issued to substantiate the portability of the IPAD system and to demonstrate **its** usefulness to the aerospace

industry. Appendix D contains a brief description of the capabilities of each incremental release.

The IPAD system will be maintained by Boeing during the development contract. The major steps for development of IPAD are shown on figure 8.0-1. These are the primary events which industry may use to plan the transitional implementation of IPAD.

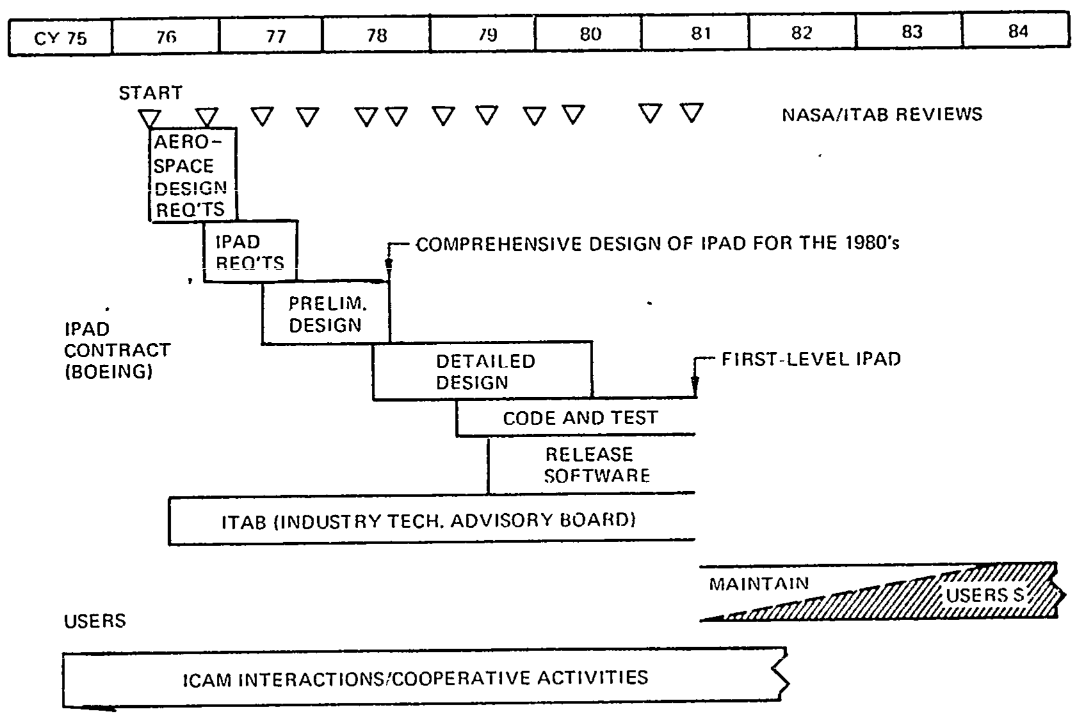


Figure 8.0-1 IPAD Development Schedule

9.0 FIRST-LEVEL IPAD PRODUCTS AND CAPABILITY

Based on the Industry Technical Advisory Board's prioritized needs and specific directions from NASA, First-Level IPAD **was** undertaken **to** implement a prototype engineering data management system suitable for distributed data base processing, The primary goal was to establish proof of concepts of the multischema architecture for an engineering data base management system. In addition, network communications capability was to be developed that would emphasize data communications and support system demonstrations. The initial host development computers for First-Level software are a CDC CYBLR 720/NOS and a DEC VAX **11/780, and** ***planning is underway*** for migration to an IDM/VM/CMS computer complex.

9.1 PRODUCTS AND CAPABILITIES

Early development of First-Level IPAD included some experimental and prototype software products, Relational Information Manager **(RIM)** (ret. 29) and the IPAD integration prototype, (ref. 23). The primary products of First-Level IPAD include data management, network, geometry, graphics, and limited user interface software. In addition, engineering **applications** and demonstrations will be developed and delivered with the **system.**

Data management is primarily a CDC host function and is carried out by the IPAD Information Processor (IPIP). The IPIP capabilities include data definition, data manipulation by application programs **and** ad **hoc user queries.** The data **definition** facility allows for network, hierarchical and relational **data** structures, separately or in combination. In addition, **a data set** ownership facility allows a user separation and control of his own data. Geometric data has been given special attention and the system supports specialized geometric primatives and a geometric processing. The data management system is designed for distributed data management and will also support distributed processing. The distributed data management capability will include support of integrated and interfaced programs executing on the DEC host requesting data from or sending data to the data manager on the CDC host. Real time queries on the DEC host are possible.

The network software supports **high-speed communications** between a CDC host and a DEC host using Network Systems hyperchannel hardware to achieve 50-million-bit-per-second communications capability. The network software provides **data communication** between the two hosts, supports execution of application programs on either host from **either host, and provides**

access to the data management capabilities on the CDC host from user requests on the DEC host.

The geometry, graphic, and **user** interface capabilities are divided between IPAD functions on the DEC and CDC computers. The DEC functions primarily support the geometry aspects of design creation and provide for pre- and postprocessors associated with the design drafting capability of AD-2000 (ref. 28). The CDC host functions supporting this capability are the standard graphics display utilities, the General Purpose Graphics System (GPGS-F) (ref. 25). In addition, the CYBER function to support geometric transformations is being developed to address the trend towards an ANI standard (ref. 26).

The IPAD applications and demonstrations cover a broad spectrum of engineering activities. The demonstrations utilize both the CDC and the DEC computers and cover areas of analysis, design, project management, and the interaction of design with manufacturing. Goals for increased engineering effectiveness in an IPAD environment are being established with ITAB support. During demonstrations, data will be gathered and compared with these goals.

Figure **9.1-1** illustrates the variety of IPAD applications that will be the substance of the demonstrations. This matrix shows the particular Functions within First-Level IPAD and the application programs to be developed to support the IPAD demonstrations. The matrix also illustrates the First-Level developments as contrasted with the probable future Second-Level and Third-Level developments.

9.2 MIGRATION OF FIRST-LEVEL CAPABILlTY TO IBM COMPUTER COMPLEX

Plans are to begin, in 19817, the migration of the First-Level software products from the CDC/DEC host environment to include an IBM host complex. Associated with this migration would be an appropriate set of applications and demonstrations, similar in character to those for the CDC/DEC equipment. These demonstrations will be conducted to show the versatility and portability of the IPAD software.

9.3 MANUFACTURING DATA BASE MANAGEMENT SYSTEM REQUIREMENTS

A preliminary document (ref. 24) describes the data base management requirements of the manufacturing process. This document utilizes the work on the sheet metal wedge from the ICAM program (ref. 27) and traces the process of manufacturing of a sheet metal part and as well as its interaction with the design process. This **work** provides an initial assessment of the potential of IPAD software in supporting manufacturing activities

and helps define where IPAD enhancements are needed, This activity is closely coordinated with work on CAM data management requirements carried out under the ICAM program.

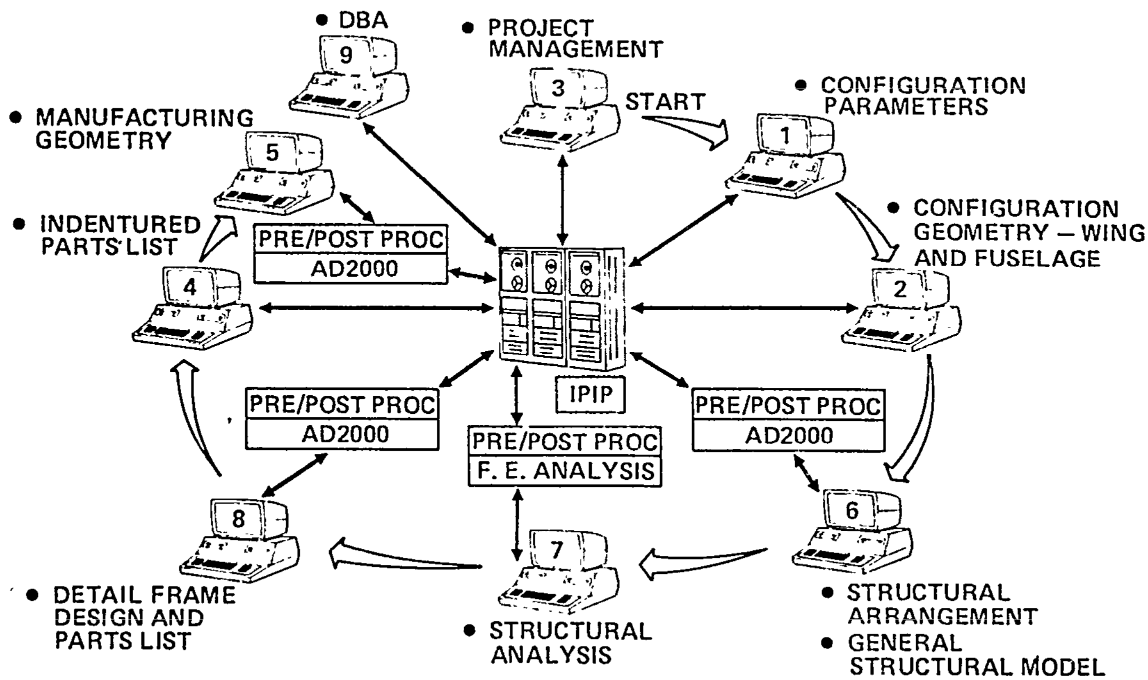


Figure 9.1-1 First-Level IPAD Integrated Demo

10.0 EXTENSIONS TO FIRST-LEVEL SOFTWARE (SECOND-LEVEL IPAD) PRELIMINARY DIRECTIONS

Considerations are underway to improve the performance and extend the capabilities of First-Level IPAD to produce Second-Level IPAD software and technology which will be more useful to engineers in a product development environment. The following capability extensions are under consideration and have been prioritized by ITAB in order of high to low priority. Decisions on specific capabilities to be developed will be made following appropriate NASA and industry review, as well as through consideration of manufacturing needs identified through cooperative efforts with the ICAM program.

10.1 HIGH LEVEL DATA MANAGEMENT

This package would provide capabilities for easy organization, control, and use of all required kinds of data in a large, integrated production engineering environment. The capabilities for establishing an information bank supporting hierarchical ownership and control of data would be provided. The capabilities would be suitable for storing of data developed and used by a large engineering organization involved in the detailed design of a production aircraft. Organization of data should provide hierarchical structuring in successively smaller blocks, with ownership established at each node in the tree. Control of data should provide an owner with rules, standards, access, update, and version control for all or selected parts of the data under individual ownership. Engineering data (including that contained in engineering drawings and information used in engineering/manufacturing interactions) must be supported.

10.2 DATA PROTECTION AND SECURITY

This package would provide capabilities for reliability, security, restart, and recovery. Second-Level IPAD should be suitable for production usage and comply with company proprietary data handling requirements. No special provision would be made for classified information except that it will be possible to use physical isolation for processing such information. Second-Level IPAD would (7) have facilities for keeping records of data accesses, (2) enforce appropriate user identification, (3) meet system reliability requirements (both hardware and software), and (4) make adequate provision for journaling, backup, and recovery.

10.3 DISTRIBUTED FUNCTIONALITY AND USER INTERFACE

This package would provide a uniform and user-friendly user interface, including capabilities for transparency of functionality. A uniform, transparent user interface would be provided that would foster the use of Second-Level IPAD in a production engineering environment. A common user-oriented command language would be provided for all hosts. IPAD functions would be distributed in a fashion transparent to the user, and a facility provided to make possible the integration of applications, the locations of which are transparent to the user.

10.4 PROJECT MANAGEMENT SUPPORT

This package would provide capabilities for support of engineering management, including project planning and monitoring. These capabilities would include facilities to store, control, and use planning data, such as resources and milestones, as well as performance data relative to the plans. To integrate the management and the engineering performance functions, the engineering data would be related to the management data, and release of engineering data would automatically trigger recording of milestone completion. Conversely, the planning data could be evaluated against the engineering data to notify management and the responsible engineers of upcoming milestones or to give a history of schedule performance.

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ITAB

NASA-IPO

APPENDIX A

INDUSTRY INVOLVEMENT IN IPAD SYSTEM DEVELOPMENT

BACKGROUND

The definition of IPAD has evolved over many years from a study and critique process that included extensive aerospace industry involvement. Two in-depth studies of the feasibility and possible forms of an IPAD system were carried out by the Boeing Company and General Dynamics/Convair (see refs. 1 and 2). The total cost of these studies over a 17-month period was $611,000. Each study contractor undertook a careful dissection of the vehicle design process to delineate those functions and tasks that can be beneficially supported by computer hardware and software and then defined the format and elements of a software system that could substantially improve the design process. They also assessed the impact of this IPAD system on company computer hardware requirements and on the performance of company staffs and evaluated its cost and benefit potential.

One company examined these questions in the context of design of three kinds of vehicles--a large subsonic transport, a supersonic transport, and a hydrofoil--and developed a comprehensive, detailed picture of the design process as a multilayered network of functions. The other examined intensively the tasks and interfaces of individual designers and groups and analyzed carefully the information flow in design. They considered the effects of the detailed constituent parts of the design process and extrapolated their experience with existing software systems to arrive at computer requirements, costs, and benefits of IPAD software. Both concluded that IPAD is feasible and will fit on existing computers. They arrived at software systems that differed in detail, but exhibited the same general characteristics and order-of-magnitude costs. Projected benefits included 25-90 percent time and 20-60 percent cost savings in design, better management visibility, and reduced risk and cost resulting from greater depth in early trade-offs, on-time designs, and fewer design changes during production.

Results of these studies were presented in four oral reports that were well attended by representatives of industry; for example, 83 industry representatives attended the final oral presentations. Following completion of the studies, the results were critiqued by teams from McDonnell Aircraft Co.; Lockheed-Georgia Co.; Grumman Aerospace Corp.; Rockwell International corp., Los Angeles Aircraft Div.; Control Data Corp.; IBM Corp.; and Sperry Univac. These firms examined such questions as completeness of the studies, credibility of the proposed systems and projected development parameters, user acceptance, and government and industry roles. They expended significant effort

over four months, employing 31 team members and about 100 part-time consultants, The critique reports (refs. 3-10) reveal a wide spectrum of views, but strong consensus that IPAD development should proceed, should not include technical module development which should remain largely the prerogative of industry, and should provide early delivery of software and user involvement. Because of the inevitable budget limitations, it was recommended that NASA limit its specific objective to production of a truncated, but "working". system.

Other evaluations of IPAD include an Army-funded study by McDonnell Douglas Astronautics Co. of its benefit potential for missile design (ref. 11) and a small NASA-funded study by Battelle Columbus Laboratories of its potential for non-aerospace application (Ref. 13). In addition, the NASA Research and Technology Advisory Committee (RTAC) on Materials and Structures sponsored a colloquium of high-level aerospace managers at MIT on January 30-31, 1974, at which IPAD was examined and discussed (ref. 12). NASA published an IPAD "Prospectus" in February 1975, which set forth the plan for development, initial maintenance, and release of IPAD; for an Industry Technical Advisory Board (ITAB) to advise the IPAD contractor, and for a user-controlled organization to accept maintenance responsibility for IPAD software. NASA then conducted a survey of 41 aerospace companies seeking their commitment to become a member of ITAB during IPAD development; to evaluate IPAD software before it is generally released; and to financially support, in the context of a user-controlled organization, maintenance and improvement of IPAD software after its value to their company had been demonstrated. A summary of the responses is given in the attached table (Figure A-l) according to company categories. Two messages of a general nature were apparent in the responses. First, support for the IPAD concept and willingness to provide advice and counsel through the ITAB was very good from the large and medium airframe companies for whom IPAD would be primarily tailored, Second, most companies prudently preferred to defer hard commitments beyond ITAB participation until they had a chance to assess results. A few companies specifically declined commitments to participate in the IPAD project, and these fell in two categories; either IPAD did not appear to meet needs of their particular design process; or they saw IPAD aimed at design problems larger than their company activity, Several such companies wished to remain informed on IPAD progress with an opportunity to re-evaluate their position later.

Company	Letters		ITAB Member?				Eval. Software?				Support User GP?			
	Sent	Replies	Yes	EL	NS	No	Yes	EL	NS	No	Yes	EL	NS	No
Major Airframe[1]	15	15*	15				4	9	2		1	10	4	
Medium Airframe	6	5	4			1			4	1	2		2	1
Light Airframe	5	4		1		3		1		3		1		3
Helicopter	4	4	2	1		1		2	2			2	2	
Engine[2]	5	5*	3			2	2	1		2		3		2
Other	2	2		1		1		1		1		1		1
Computer	4	4	2		1	1	1	1	1	1	1	1	1	1
	41	39	26	3	1	9	7	15	9	8	4	18	9	8

[1]represents 6 corporations
[2]represents 4 corporations

EL Evaluate position later
NS Not specific

* Some replies provided by other companies in a corporation or through a corporate reply

Figure A-1 Industry Response To IPAD Prospectus

CURRENT INVOLVEMENT

The Industry Technical Advisory Board **(ITAB)** was formed by the development contractor soon after contract initiation to afford industry the maximum opportunity for influencing the course of **IPAD** development. ITAD consists of members and observers representing major **U.S.** aerospace and computer companies, and meets periodically. The ITAB structure is illustrated by Figure A-2. ITAB activities include review of planning and technical documents, critique of key development decisions, ranking of IPAD requirements, identification or demonstration programs, and consideration of the formation of an IPAD user group.

INDUSTRY TECHNICAL ADVISORY BOARD (ITAB)

W.E.SWANSON
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EXECUTIVE OFFICER/INTERFACE MANAGER
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- MEMBERS
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    - FAIRCHILD
    - GENERAL DYNAMICS
    - GRUMMAN
    - LOCKHEED
    - MARTIN-MARIETTA
    - MCDONNELL-DOUGLAS
    - NORTHROP
    - ROCKWELL INTL
    - VOUGHT
  - ENGINE MANUFACTURERS
    - GENERAL ELECTRIC
    - PRATT AND WHITNEY
  - COMPUTER MANUFACTURERS
    - IBM
    - CDC
    - DEC
    - UNIVAC
- OBSERVERS
  - ADVANCE MARINE ENTERPRISES
  - AVCO - LYCOMING
  - BATTELLE
  - BELL HELICOPTER
  - COMPUTERVISION
  - DENELCOR
  - FORD
  - GTE
  - GENERAL MOTORS
  - GERBER SCIENTIFIC INSTRUMENT
  - GULFSTREAM AMERICAN
  - HIGHER ORDER SOFTWARE
  - HUGHES AIRCRAFT
  - MACNEAL SCHWENDLER
  - MANUFACTURING AND CONSULTING SERVICES
  - NATIONAL BUREAU OF STANDARDS
  - NAVAL AIR SYSTEMS COMMAND
  - NASA
  - NETWORK SYSTEMS
  - PIPER AIRCRAFT
  - PRIME COMPUTER
  - RENSSELAER POLYTECHNIC INSTITUTE
  - RESEARCH TRIANGLE INSTITUTE
  - ROYAL GRAPHICS
  - SOFTECH
  - STRUCTURAL DYNAMICS RESEARCH
  - TEKTRONIX
  - TEXAS A&M
  - TRW
  - UNIVERSITY OF MISSOURI-ROLLA
  - VIRGINIA POLYTECHNIC
  - WESTINGHOUSE

Figure A-2 Industry Technical Advisory Board (ITAB)

APPENDIX B

IPAD DEVELOPMENT PHILOSOPHY

The IPAD development philosophy is to produce a user oriented interactive system with portability as a design objective, The system design makes provisions for extending its capabilty as an open-ended evolutionary process having minimum impact on users of the system. The following are major considerations supporting this development philosophy.

A systematic software development process is used consisting of the following principal steps:

User specification of requirements (ref. 18 and 19)

Analysis of user requirements (ref. 22)

System preliminary design (ref. 21)

System detail design

System coding

system development tests

System acceptance tests

System installation/maintenance

Each step is documented completely to provide continuity of system development. The requirements have been developed to encompass the entire engineering design process, its interface with other organizations and user needs. These requirements are being used to produce the preliminary design of a "Full" IPAD system. The cost and time to develop individual IPAD system modules, a priority ranking of the requirements, and a definition of the basic IPAD software components will be used to identify the "First Level" IPAD system within the constraints of the contracted funds available. The "First Level" IPAD is a subset of "Full" IPAD and will be capable of extension to "Full" IPAD.

Since the IPAD development is long term, incremental releases have been planned. Preliminary design will be completed for "Full" IPAD and the remaining steps--detail design through user training--will be done for "First Level" IPAD for each incremental release on two host computing systems.

The IPAD development is driven by the requirement to produce an effective interactive user oriented system. This requirement

is addressed by developing models of the user interface and other systems interface as part of IPAD preliminary design. These models are used for walk through scenarios posed by engineers to test the primary functional requirements of the IPAD system. The tests further substantiate the computing staff's understanding of the requirements and help formulate the language syntax that IPAD will display during terminal operations.

Modular development will be used throughout IPAD to improve visibility of functional elements of the IPAD system and to facilitate testing and implementation. Machine dependencies will be minimized and isolated within interface modules wherever practical. Other advantages of developing a modular system include: improved ability to deactivate optional functions, ease in isolating changes to the system, and ease of installation of new functional modules.

IPAD will be implemented in a high level system implementation language for two major computing systems to make its initial use available to many companies and to test the capability to transfer the system from one host to another.

The acceptance testing conducted by the IPAD engineering development team will include execution of typical application programs based on scenarios developed to demonstrate the usefulness of IPAD. These application programs are obtained from or released to the public domain and will be delivered with IPAD to provide an initial technical capability which demonstrates functional capabilities of IPAD.

APPENDIX C

KEY SPECIFICATIONS

This appendix contains a summary of key IPAD specifications relative to performance of the Full IPAD system,

HARDWARE CONFIGURATIONS

The IPAD system shall support processing on computer hardware complexes supplied and maintained by each company incorporating the IPAD system. IPAD shall be Capable of distribution over multiple processors or of operating on a single processor. In addition, other computing systems can be interfaced to IPAD as satellite computing systems. The following ranges of hardware configurations shall be possible:

1-4 large scale computer systems

0-100 remote satellite computer systems

100-800 interactive terminals (approximately 25% will be used in graphical mode and 75% in text mode).

As a minimum, the IPAD system shall be compatible with the following computing systems:

CDC CYBER 170 Series

IBM 370 Series

DEC PDP 11/70

SIZE OF DATA BASE

The data volumes and data processing activities that IPAD supports vary from company to company. The following guidelines establish the upper bound or data volumes.

Two product development processes through detail design are in progress at any given time. The data storage required is:

Immediate access - 150 billion bits

Archive (10 min. access] - 190 billion bits

Archive (24 hr. access} - 360 billion bits

Ten products are undergoing sustaining design. For this activity, **it is** assumed that 20% of the total sustaining design data is required for current work and requires immediate access; 40% consists of archived drawings which must be available **within 10** minutes; and the remaining 40% is also archived and must be available within 24 hours. The data storage required is:

Immediate access - 470 billion bits

Archive (10 min. access) **- 940 billion** bits

Archive (24 hr. access) - 940 billion bits

Preliminary design, of exploratory nature of 10 products per year. Data storage required:

Immediate access - 100 billion **bits**

Archive (24 hr. access) - 620 billion bits

For archival purposes, it is assumed that there is a continued increase of data volume that corresponds to one product description (dietailed design) every two years and **10%** of the information developed during exploratory preliminary design. The annual increase in data storage is:

Archive (24 hr. access) - **310** billion bits

The bounds of data storage required are as follows (the lower bound is assumed to be approximately 10% of the upper bound):

	Lower Bound	Upper Bound	Annual Growth
Immediate access (billion bits)	70	720	
Archive - **10 min.** access (billion bits)	310	1130	
Archive - 24 hr. access (billion bits)	190	**1920**	310

RESPONSE

The IPAD system monitors response time and controls access to the system when response time is above a parameter set by each company using IPAD. Response time is defined as the time elapsed between the last input by the user and the first character displayed by the computer. The response times given are those for

which the user will be comfortable and continue to utilize the terminal for his purposes. The following are design goals:

(15 to 60 seconds)

Access functions where the user is familiar with the delay.

Single enquiries where the user is familiar with the delay, cued by a message from the computer within two seconds acknowledging the command.

System failures and recoveries, cued, where possible, by a message from the computer within two seconds warning of the delay.

Loading of programs and data for execution and processing, cued by a message within two seconds acknowledging the command.

Restart from a prior session.

(4 to 15 seconds)

Low key enquiry dialogue possible but awkward.

Intense creative dialogue not possible.

(2 to 4 seconds}

Complex enquiries where continuity of thought is necessary.

Initial acknowledgment by the system that it is "listening."

Error messages.

(Less than 2 seconds)

Intense creative dialog.

Acknowledgment by the system that a command has been received.

Response to a paging request through a keyboard.

(Less than 1 second)

Response to a paging request using a light pen.

Development of geometric entities.

(Less than 0.1 seconds)

Brightening of characters from a light pen selection.

Appearance of a line when using the light pen as a drawing stylus.

Appearance of a character from a CRT keyboard input.

The critical threshold for effective creative dialogue is two seconds. Beyond two seconds mental efficiency degrades rapidly and delays beyond fifteen seconds are structured to relieve the user of both mental and physical captivity (see ref. 1, vol. 4).

ACCURACY

The system accuracy will be to store numerical data with at least 10 significant digits and to perform arithmetic operations with no additional loss of accuracy other than that imposed by purely mathematical considerations and the characteristics of arithmetic operations of the host computing system.

EFFICIENCY

At all times the active system configuration will be structured on a minimum system functional support consistent with the user needs. The responsibility for efficient operation is a system design requirement and the user is not required to guide the system into its most cost effective support.

RELIABILITY

During any consecutive four week period, the minimum average user availability for the IPAD system is not less than 97.5% of the total available host computing time allocated to IPAD. The IPAD system is considered available when a user is able to productively perform his desired objectives.

TRANSPORTABILITY

The system design shall be as machine-independent as possible and its operation shall be demonstrated on CDC and IBM computers. It is intended that the system will be used on other existing computing systems and be adaptable to future computing systems.

APPENDIX D

DESCRIPTION OF INCREMENTAL RELEASES

IPAD INTEGRATION PROTOTYPE SOFTWARE--RELEASE 0.0

The first release of IPAD software was made in October 1979, It consists of the prototype information management system, (RIM) an integration package, CDC/DEC communications software based on the Hyperchannel link, and various other software packages available for IPAD use and distribution and which have been integrated within the prototype. It permits IPAD users to create geometry on the DEC host, transmit this geometry over the high-speed network to the CDC host where it is inserted into the IPAD prototype data base, and finally to Connect the geometric model to a finite element model and execute ATLAS and SPAR programs- Query and display capabilities of the results are available with this package, The specific software available under this release is:

- IPAD Integration Prototype System
  - Prototype GRTS (RG Library)
  - Patch II Display (RD Library)
  - Patch II User Interface (RU Library)
  - IPAD Integration Prototype
    - AD-2000 Postprocessor to RIM
    - Finite Element Modeler
    - Preprocessor to ATLAS and SPAR
    - Postprocessor to ATLAS
- RIM II (Relational Information Manager)
- GPGS-F (A Graphical Display System)
- Design Drafting Pre/Postprocessor (AD-2000 PDP 11/70 IAS)
- Pascal Compiler
- CDC/DEC Communications package
- SPAR (Finite Element Program)
- ATLAS (Finite Element Program)

FIRST-LEVEL IPAD, RELEASES 1.0-3.0

These are incremental releases of First-Level IPAD software, each building upon the previous release, Release 1.0 provides the fundamental data management capabilities and the internal

communications facility for the CYBER. It can be used to demonstrate fundamental data processing capabilities of IPIP and make an assessment of its performance characteristics, In Release 2.0, the data definition and manipulation facilities of the data manager are added, Release 3.O adds the query processor, the IPIP geometry processing capabilities, VAX based capabilities, the interhost communications, remaining executive services (including performance measurement), and IPIP suppport for ANSI geometry transformations and CODASYL set processing..

A more detailed description of the functionality of these releases in relation to the functional architecture of First-Level IPAD is contained in the following,

First-Level IPAD Functional Architecture

A hierarchical breakdown of First-Level IPAD functional capability is contained in figure D-1.

IPAD Information Processor, IPIP

IPIP contains two main functional subcomponents, the data manager and language interfaces, The data manager provides all data processing capabilities including multiuser threading, mapping, binding and physical storage and retrieval of data. It performs record processing, CODASYL set processing and structure' processing, where a structure is a record aggregate. Structure processing supports IPAD geometry requirements including transformations between IPAD and ANSI representations for geometry. The language interfaces subcomponent provides IPIP user language processing and query processing. The language processors reside on separate system control points and communicate with the data manager through the IPEX communications capability.

IPAD Executive, IPEX

IPEX provides a common set of executive services for IPAD software and for application programmers which integrate or interface programs into IPAD. It has two main functional subcomponents, the service routines and the communications facility. The service routines provide functions for data transformations between the IPAD network standard and host formats, gather and reduce performance data to usable form and provide access to fundamental host services like file I/O, terminal I/O, timing, etc. The communications facility provides a host independent software interface to a high level protocol for either intrahost or interhost communications.

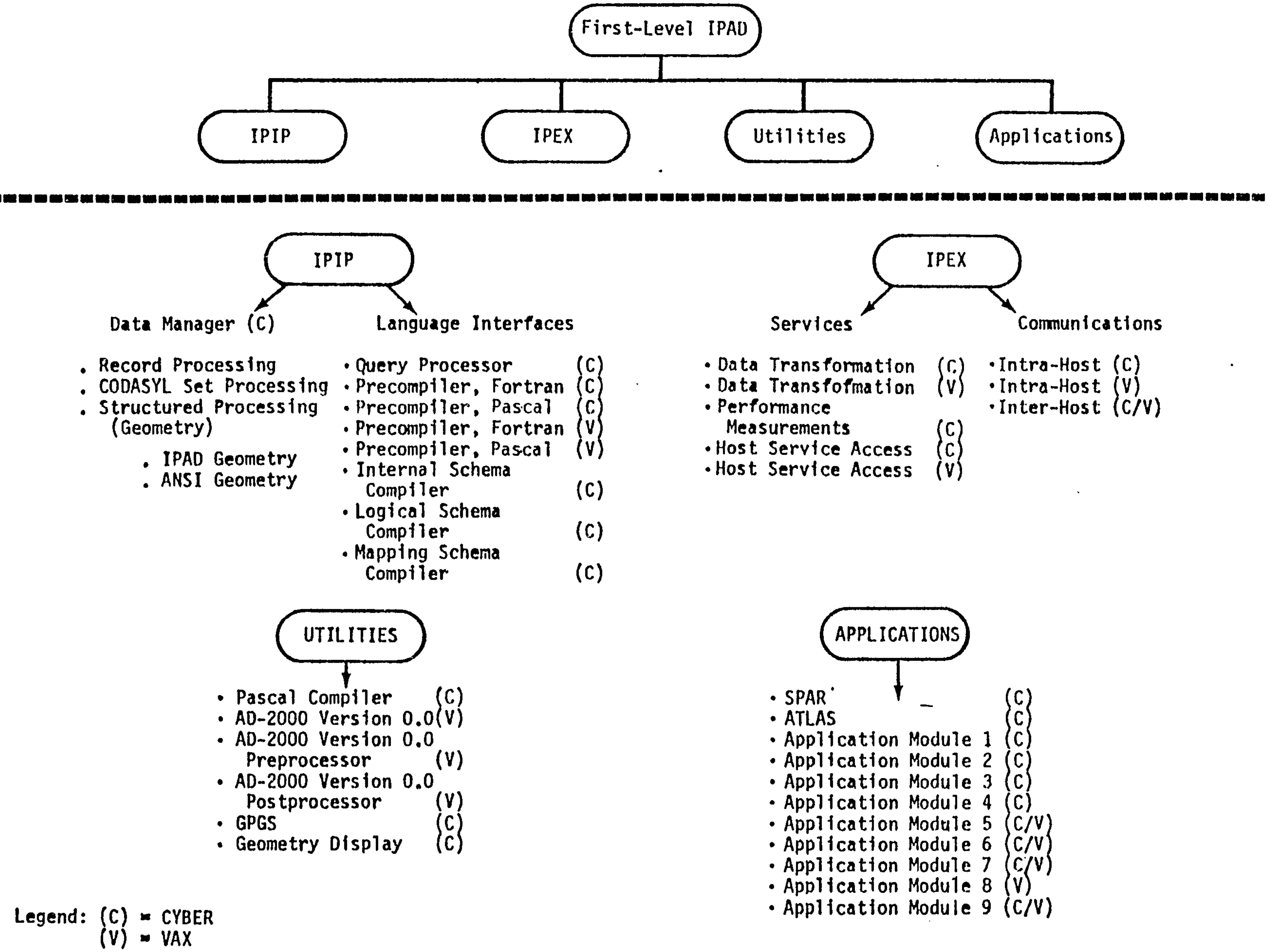

Figure D-1-- FIRST-LEVEL IPAD FUNCTIONAL ARCHITECTURE

IPAD Utilities

These utilities provide services to application programmers and engineers using IPAD, The Pascai compiler transforms Pascal source programs to executable form. AD-2000 Version 0.0 is an IPAD design/drafting system. AD-2000 Version 0.0 pre- and post-processors interface AD-2000 Version 0.0 with IPIP. GPGS is a device independent graphics routine library which adheres to the ACM SIGGRAPH graphic standard, The geometry display utility provides the IPAD engineering user with a GPGS-based Capability to view geometry stored in IPIP in IPAD standard form.

Applications

The IPAD applications contain integrated or interfaced user application programs that have teen developed, augmented, or modified to support the engineering demonstrations of First-Level IPAD. ATLAS and SPAR are general purpose finite element programs for structural, weights, loads and aerodynamic analyses. The application modules are intended for demonstrations only. They provide the following functions:

Module#	Function
1	Configuration Parameters
2	General Arrangement
3	Project Management
4	Indentured Parts List
5	Manufacturing Geometry
6	Structural Arrangement
7	Structural Analysis
8	Detail Frame Design
9	Data Base Administration

First-Level IPAD Release 1.0

This release contains the following functional subcomponents:

IPIP Data Manager, Record Processing
IPEX Service for Data Transformation between CYBER and the network standard
IPEX CYBER Host Service Access as required
IPEX CYBER Intrahost communications
CYBER Pascal Compiler
GPGS

First-level IPAD, Release 2.0

This release contains all of Release 1.0 and the following functional ccmponents:

Data Definition Language Compilers
CYBER Data Manipulation precompilers
Application Module 7
AD-2000, Version 0.0
ATLAS
SPAR

First-Level IPAD, Release 3.0

This release contains all of Release 2.0 and the following functional components:

Query Processor
IPIP Structure Processing Capability for IPAD Geometry
Application Modules 3, 4
VAX Data Manipulation Precompilers
Interhost Communication
Performance Measurements
CODASYL Set Processing Capability in IPIP
ANSI Geometry Support in IPIP
Geometry Display Utility
AD-2000 Version 0.0 Pre- and postprocessor
Application Modules 1, 2, 5, 6, 8, 9
VAX Data Transformation Service
VAX Host Service Access
VAX Intrahost Communication

FITNESS FOR PURPOSE:
A NEW LOOK AT WELD DEFECT ACCEPTANCE CRITERIA

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Dr. Sandor is currently responsible for research programs to improve welding technology in the U.S. shipbuilding industry. He is also a Professor of Materials Science at Widener University in Chester, Pennsylvania.

Dr. Sandor has attended schools in Hungary, England, and the United States, and holds a doctorate in metallurgical science. His experience is research oriented, but interspersed with production and academic environments.

ABSTRACT

This presentation highlights the results of the "Weld Defect Tolerance Study" published under the Ship Producibility Program in June 1980. It is shown that the repair of innocuous defects currently adds $0.5 million to $1.0 million per ship in unnecessary cost, and that the end result in many cases may be even more deleterious to the completed structure. An update is provided on action being taken in the industry to improve/develop more rational acceptance standards for certain defects.

This paper describes the more important points of a project entitled “Weld Defect Tolerance Study”. The basic thrust of understanding the real significance of weld defects is to decrease the cost of welded constructions through eliminating unneccesary repair of harmless weld discontinuites.

The focal point of the first phase of the study was commercial ship hull welds. Subsequently, and in response to shipbuilding industry recommendations arising from results of Phase I, a similar study is now underway on naval surface ships constructed from mild steel. It, was found that the repair of innocuous discontinuities consisting primarily of porosity and slag inclusions adds $0.5 million to $1.0 million per ship in superfluous cost and the quality of the end product in many cases is even more deleterious to the integrity of the structure than had the harmless defect been left in the weldment unrepaired.

When failure in commercial ship hulls occurs., fatigue was found to be the dominant failure mode caused primarily by inferior design details and unsatisfactory joint fit ups or misalignments. Several other non-weld related causes were reported in the published literature. This suggests that existing weld acceptance standards are overly conservative. A survey of national and international publications on weld defects and an analysis of quality control data obtained from major U.S. shipyards show clearly the need to establish more rational weld acceptance standards than the current, workmanship-type standards.

Collection of data and information that reflect the actual events of manufacturing processes and systematic monitoring of the performance of ships are essential to the generation of rational weld acceptance standards formulated from statistical approaches and fracture mechanics principles- of relevance with respect to failure mode.

Since failures in sea-going vessels may be induced by many different causes, the introduction of the "Quality Control Systems Loop" Seems to be a logical approach to ship hull construction and a cost effective use of resources. Fitness-for-service, QCSL - an integral part of which is NDT - compliment one another for several reasons. Perhaps the single most important reason is that they are destined by definition to improve quality at the lowest possible cost. The fitness-for-service, QCSL, as well as NDT, require an orderly development and their full coordination in order to maximize their effectiveness. The rudimental tenets of fitness-for-service (purpose) and QCSL are good understandings of, and earnest appreciations for everything that takes place in the total system. The total system is not merely confined to what happens within the shipyard, but also includes in-service performance of the product of the specific shipyard. In other words, it is very important for everyone to know what takes place in the yard as well as at sea so that cause-and-effect relationships may be well established. Fitness-for-service and QCSL coupled together are bound to drastically decrease "quess work". Examples of Fitness-for-Purpose standards for slag and porosity, and of QCSL are shown in Fig. l-2.

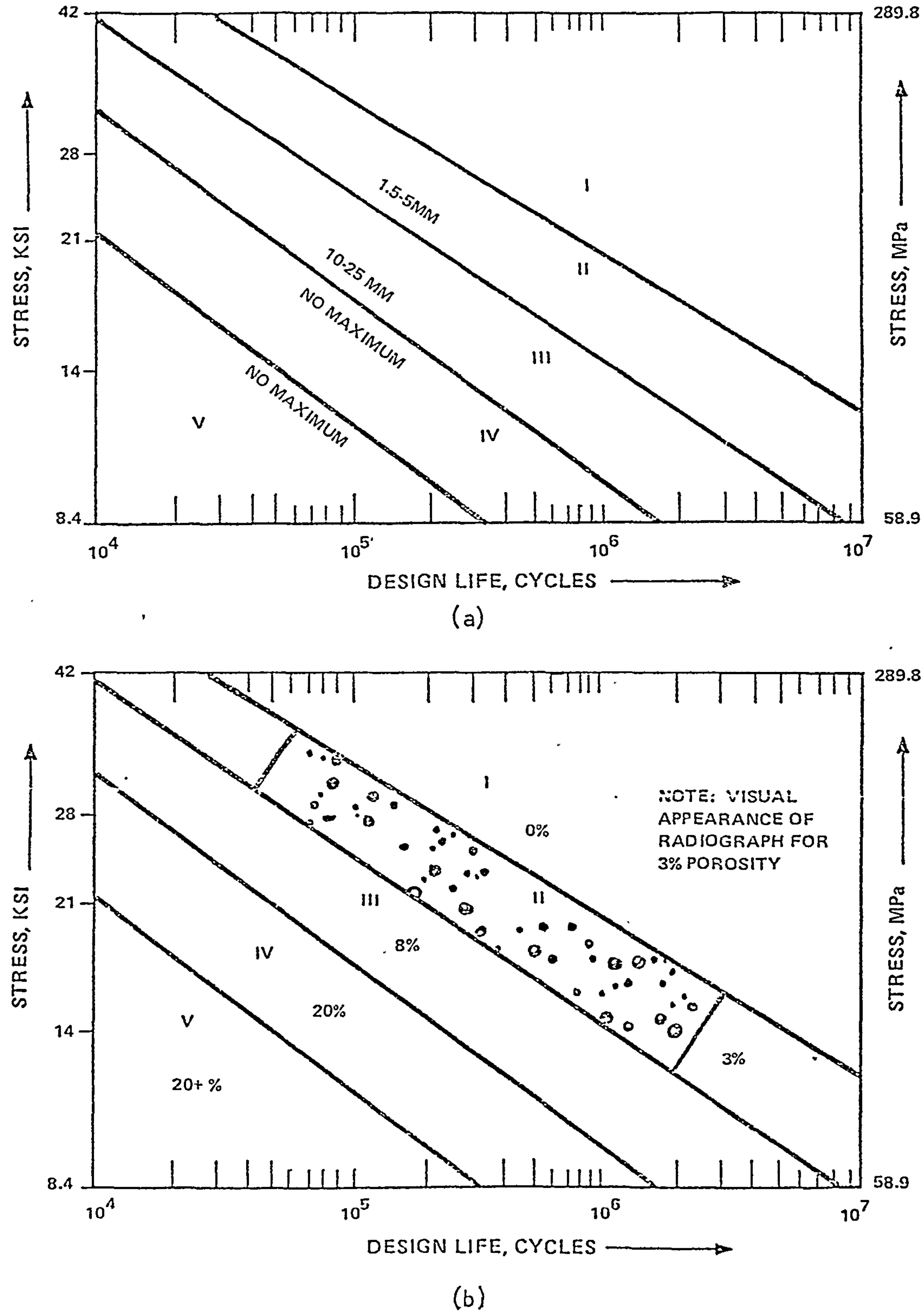


FIGURE 1--Proposed standards for (a) SLAG INCLUSIONS (any plate thickness) and (b) POROSITY in "as-welded" carbon-manganese steel.

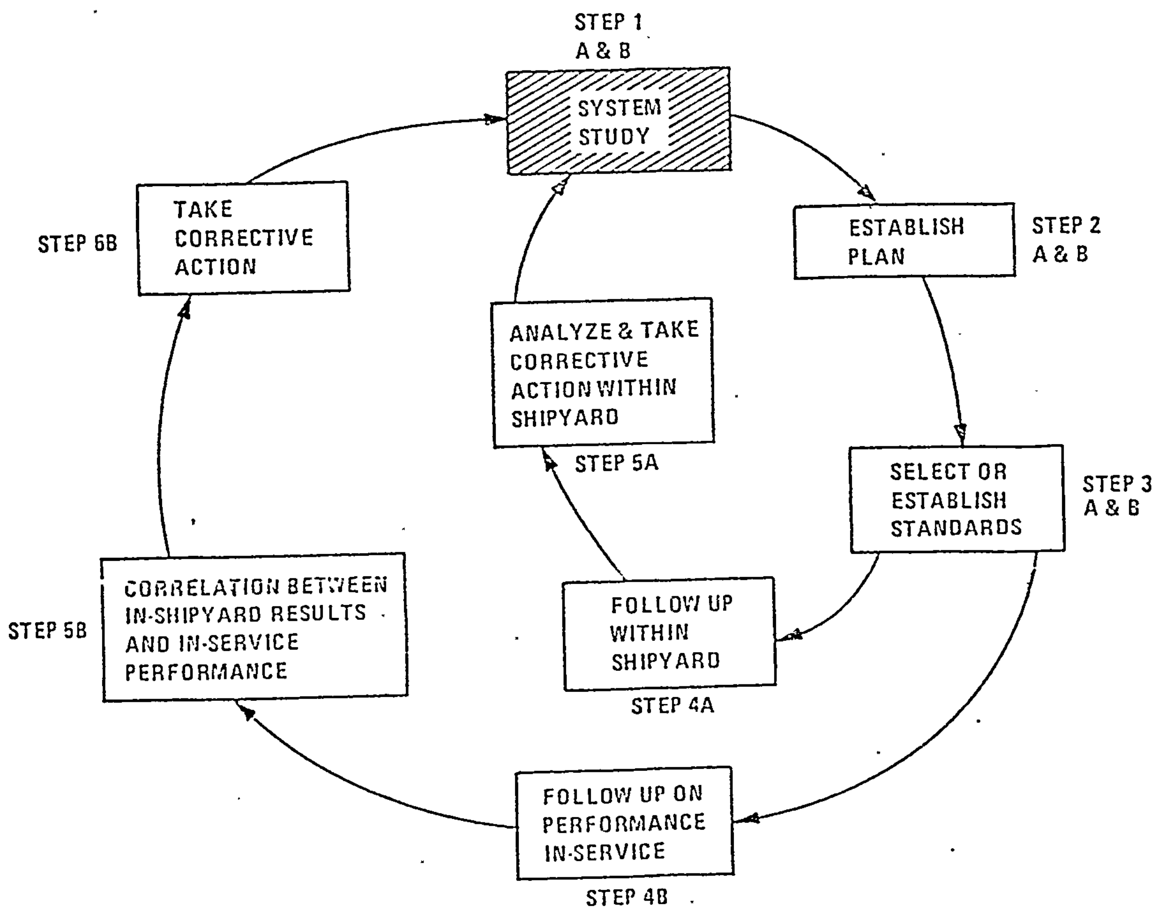


FIGURE 2--A schematic diagram of QCSL. Loop "A" represents in-shipyard scenario for short-range benefits. Loop "B" encompasses in-shipyard and in-service performance yielding long-range gains.

More specific details of Phase I study are given in the following captioned slides.

1. <u>WHY STUDY WELD DISCONTINUITIES</u>

(A) INTRODUCTION OF DEFECTS INTO WELDS IS UNAVOIDABLE,

(B) NOT ALL DEFECTS ARE HARMFUL,

(c) REPAIRING INNOCUOUS DEFECTS ENTAILS UNNECESSARY COSTS,

II, <u>WHAT IS THE REAL PURPOSE OF WELD DEFECT TOLERANCE</u>?

(A) OUTLINING OF CONDITIONS FOR AVOIDING SUPERFLUOUS WELD REPAIR COSTS AND WELDMENT DEGRADATION IN GENERAL AND NOT LOWERING OF PRODUCT QUALITY,

(B) "A FITNESS FOR PURPOSE" PHILOSOPHY,

III. WHAT KINDS OF WFLD DEFECTS ARE THERE?

(A) CRACK OR CRACK-LIKE DISCONTINUITIES.

(B) POROSITY, SLAG INCLUSIONS,

(C) LOF, LOP,

(D) GEOMETRIC DISCONTINUITY,

ANOTHER CATEGORIZATION:

(A) PLANAR,

(B) NON-PLANAR,

CATEGORIZATION BY LOCATION:

(A) SURFACE,

(B) BURIED,

(c) THROUGH-THICKNESS,

IV, WHAT FACTORS DETERMINE THE SIGNIFICANCE OF THE DEFECTS?

- TYPE
- SIZE
- SHAPE
- AMOUNT
- DISTRIBUTION
- ORIENTATION
- LOCATION

OF DEFECT

V. WHAT ELSE IS NEEDED FOR ASSESSING WELD DEFECTS?

1. PRINCIPAL STRESSES,
2. ENVIRONMENTAL PARAMETERS,
3. DESIGN CONDITIONS','
4. MANUFACTURING CONDITIONS,

VI. WHAT IS THE BASIC DIFFERENCE BETWEEN PRESENT AND PENDING CODES EXPECTED FROM WELD DEFECT STUDIES?

(A) PRESENT CODES:
- HISTORICAL
- OVERCONSERVATIVE
- UNNECESSARY REPAIRS
- ASSIMILATION OF MANY CODES,
- LACK OF INTERACTION EFFECTS,

(B) PENDING CODES:
- BASED ON **FR.** M.
- ELIMINATION OF SUPERFLUOUS WELD REPAIRS
- TAILORED TO SPECIFIC INDUSTRY,

VII. UNDESIRABLE CONSEQUENCES OF WELD REPAIR

- INCREASED RESIDUAL STRESS,
- INTRODUCTION OF NEW DEFECTS,
- MICROSTRUCTURE DEGRADATION,
- AGGRAVATION OR EXTENSION OF PRE-EXISTING DEFECTS UNDETECTED DURING ORIGINAL INSPECTION,
- ADDITIONAL WELDING PERSONNEL REQUIREMENT,

WELD REPAIR DOES NOT SIGNIFY AN IPSO FACTO IMPROVEMENT,

VIII, WHAT ARE THE PRINCIPAL FAILURE MODES?

- BRITTLE FRACTURE
- FATIGUE
- GENERAL YIELD
- LEAKAGE
- CORROSION, STRESS CORROSION FATIGUE
- INSTABILITY (BUCKLING)
- CREEP (RUPTURE)

IX, WHAT IS FRACTURE MECHANICS?

- UNDERSTANDING OF DUCTILITY

- TOOL TO ASSESS TOLERABLE SIZES OF DEFECTS

X. WHAT'S INVOLVED IN **FR.** M.?

1. STRESS ANALYSIS

2. DEFECT ANALYSIS

3. MATERIAL ANALYSIS

4. ENVIRONMENT ANALYSIS

XI. WHAT DETERMINES WHICH FR. M. PRINCIPLE IS TO BE USED?

- THE FRACTURE MODE ⟶ JUDGED BY

  1. OPERATING STRESSES (LEVEL).
  2. STRESS TYPE.
  3. GEOMETRY.
  4. ENVIRONMENT.
  5. MATERIAL PROPERTIES.
  6. STRAIN RATE.

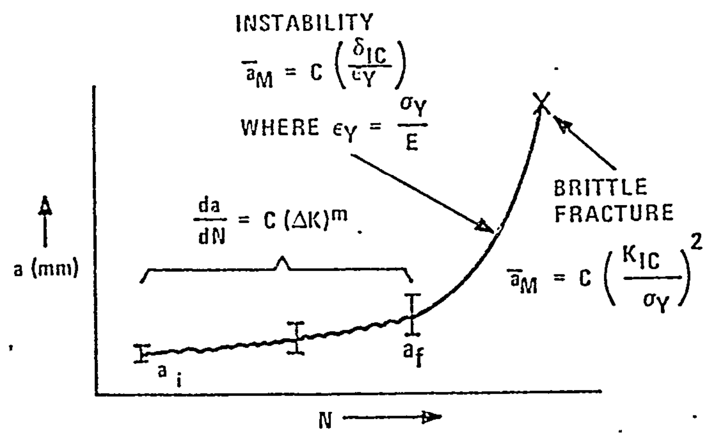
XII. WHAT ARE THE PRINCIPAL FR. M. PRINCIPLES?

1. LEFM ⟶ K_{IC} ⟶ BRITTLE FRACTURE

2. COD ⟶ δ_{IC} (UK) } GENERAL YIELD

3. J-INTEGRAL ⟶ J_{IC} (USA) } GENERAL YIELD

4. $\frac{da}{dN} = C(\Delta K)^m$ ⟶ FATIGUE FAILURE



$\bar{a}_M$ = TOLERABLE (ALLOWABLE) DEFECT PARAMETER WHICH MUST BE LESS THAN a_C.

$K_{IC} = (E\ J_{IC})^{1/2}$

$\delta_{IC} = \frac{J_{IC}}{m\sigma_Y}$

Graphical illustrations of fatigue failure mode from an incipient discontinuity (Plot of discontinuity size versus endurance).

XIII. CHARACTERIZATION OF FATIGUE FROM A FRACTURE MECHANICS POINT OF VIEW MEANS

1. SAFETY FROM CATASTROPHIC FAILURE,
2. LARGER SIZE DISCONTINUITY PERMISSIBLE,
3. UTILIZATION OF CYCLIC STRESS RANGE,
4. DISCONTINUITY DIMENSIONING, LOCATION AND INTERACTION THEREOF,
5. DETERMINATION OF CRACK PROPAGATION RATE,
6. ESTABLISHMENT OF LIMIT TO CRACK PROPAGATION,
7. SELECTION OF CONFIDENCE LEVEL,
8. QUALITY CATEGORIZATION,
9. ENVIRONMENTAL CONSIDERATIONS,

XIV. HOW DOES NDE RELATE TO FR. "M,?

1. WELD DEFECTS CONSTITUTE CENTER OF NDE.
2. DIMENSIONING.
3. DETECTION,

XV. CRITIQUE OF FR. M.

(A) ACCURACY $\longrightarrow$ F (NDE, STRESSES, TEST METHOD),

(B) NO GUARANTEE OF DEFECTS PRESENT ELSEWHERE,

(c) NO TELLING LEVEL OF CONFORMITY TO SPECIFICATIONS,

(D) 100% CONFIDENCE $\longleftrightarrow$ 100% I INSPECTION OR ENHANCEMENT BY OTHER MEANS,

(E) NO ASSURANCE OF CONFIDENCE FROM SHIP TO SHIP,

(F) DISPARITY BETWEEN ARTIFICIAL AND GENERIC DEFECT ASSESSMENT. AND DIFF. MODELS $\longrightarrow$ DIFF. RESULTS,

(G) DIFFICULTY IN DEFINING EXACT AMBIENT CONDITIONS (TEMPERATURE, SALINITY, ETC.)

XVI. CAUSES OF SHIP FAILURES

- FAILURES ARE NOT MONOPOLIZED BY A SINGLE CAUSE.

- MULTITUDE OF CAUSES,

- DOMINANT CAUSES OF FATIGUE:

  - STRUCTURAL DESIGN DETAILS

  - MISALIGNMENTS

- WELD DEFECTS RANK VERY LOW AS AN EXCLUSIVE CAUSE OF "CRACKING",

- RATIO OF ALL REPORTED CAUSES COMBINED TO WELD DISCONTINUITIES IS ~6:1.

XVII. (A) AVAILABLE STATISTICAL DATA

- TYPICALLY LESS THAN 5% OF A COMMERCIAL SHIP IS INSPECTED,

- AMOUNT OF WELD REPAIR (W.R.) DONE IN A GIVEN SHIPYARD CAN BE LOOKED AT IN DIFFERENT WAYS:

  1. W. R. IN SHOP,
  2. W. R. ON SHIPWAYS.
  3. W. R. DUE TO WELD DEFECTS EXCLUSIVELY,
  4. W. R. DUE TO WELD DEFECTS, POOR FIT UP, "COSMETIC" REASONS,
  5. W. R. ACCORDING TO WELD PROCESS USED.
  6. W. R. AS PER LINEAR FEET INSPECTED,
  7. W. R. OWING TO RANDOM OCCURENCE OF WELD DISCONTINUITIES.
  8. W. R. ACCORDING TO CODES OR OTHER REQUIREMENTS,
  9. W. R. STRICTLY IN TERMS OF FR. M. CRITERION,

XVII. (B) DATA (CONTINUED)

- OCCURRENCE OF DEFECT TYPES DEPENDS ON:

  1. WELD PROCESS USED
  2. INSPECTION METHOD APPLIED
  3. TYPE OF WELD MADE
  4. JOINT FIT UP

- RANKING OF WELD DISCONTINUITIES

  DETECTION BY RADIOGRAPHY

(A) AS PER PROCESS:

MANUAL WELDING	AUTOMATIC WELDING
1. SLAG	1. LOP
2. POROSITY	2. CRACK
3. LOP, LOF	3. POROSITY
4. CRACK	4. SLAG

(B) AS PER LINEAR FEET

1. SLAG
2. LOP
3. LOF
4. POROSITY

(c) AS PER RANDOM OCCURRENCE

1. SLAG
2. POROSITY
3. LOP
4. LOF

DETECTION BY VISUAL INSPECTION

ORDER OF IMPORTANCE OF DEFECTS

1. UNDERCUT IN FILLET WELDS
2. SURFACE POROSITY
3. UNDESIRABLE BEAD CONTOUR (WELD PROFILE)
4. CRACKS AT WELD CRATERS

TOTAL AMOUNT OF WELD REPAIR ACCORDING TO BOTH X-RAY AND VISUAL INSPECTION:

11-14%

DUE MOSTLY TO:

1. SLAG INCLUSIONS
2. LOP, LOF
3. POROSITY
4. UNDERCUT
5. CRACKS

XVIII. COST OF WELD REPAIR

- DEPENDS ON MANY FACTORS
- KNOWN TO BE AS HIGH AS $1.00 MILLION PER SHIP (E.G. LARGE TANKER) WITHOUT OVERHEAD (I.E., DIRECT COST).
- HALF OF THIS AMOUNT COULD BE SAVED THROUGH:

1. IMPROVEMENTS IN DESIGN DETAILS,
2. COMPREHENSIVE Q.C. SYSTEMS APPROACH.
3. ELIMINATION OF UNNECESSARY WELD REPAIR,
4. APPLICATION OF FR. M. TO WELD ACCEPTANCE STANDARDS,
5. SUBSTITUTION OF SMA WITH AUTOMATIC WELDING PROCESSES,
6. INTRODUCTION OF ADVANCED FABRICATION TECHNOLOGY TO ENHANCE JOINT FIT UP,
7. EDUCATION AND TRAINING,

SUMMARY

- DEFECTS ARE NOT ALWAYS HARMFUL,
- WELD REPAIR COULD BE MORE DELETERIOUS,
- DIFFERENT DEFECTS, THEIR SIGNIFICANCE IS INFLUENCED BY SEVERAL FACTORS,
- FR. M. REQUIRES STRESS, DEFECT, MATERIAL TOUGHNESS DETERMINATION AND ENVIRONMENT IN CASE OF FATIGUE,
- PURPOSE OF DEFECT TOLERANCE STUDY IS TO AVOID UNNECESSARY REPAIR, DEGRADATION, "FITNESS FOR PURPOSE",
- THERE ARE SEVERAL FAILURE MODES: IN SHIPS → FATIGUE IS PREDOMINANT,
- FR. M. IS CRITICALLY DEPENDENT ON NDE.
- FR. M. RELATES ONLY TO INSPECTED WELDMENT.
- FR. M. IS RELIABLE AND SHOULD BE ACCEPTED IN CODES FOR SHIPBUILDING,
- SHIP FAILURES ARISE FROM MANY CAUSES,
- RANKING OF WELD DEFECTS DEPEND ON SEVERAL FACTORS,
- RANGE OF WELD REPAIR AMOUNT 11-14%
- ONE HALF OF WELD REPAIR EXPENDITURES COULD BE SAVED,
- FORMATION OF TASK FORCE,
- IMPLEMENTATION OF "QC SYSTEMS LOOP",
- CLEAN UP DESIGN DETAILS, DECREASE JOINT MISALIGNMENT AND IMPROVE FABRICATION TECHNOLOGY,
- WELD DISCONTINUITIES AS SOLE CAUSE OF FAILURES IN SURFACE VESSELS HAVE LOW RANKING COMPARED TO OTHER CAUSES,
- COMPREHENSIVE QUALITY CONTROL AWARENESS THROUGH CONSTANT EDUCATION,

HULL CONSTRUCTION TOLERANCE STANDARDS

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Chester, Pennsylvania

Mr. Krehnbrink's assignment includes contracted research in a number of areas of marine technology, as well as technical support for internal operations. Several current projects deal with the development of design and production standards through the National Shipbuilding Standards program.

Mr. Krehnbrink holds a degree in structural engineering from Lehigh University, and has varied engineering and research experience prior to entering the marine field.

ABSTRACT

A project to develop a trial set of representative hull construction tolerance standards has been undertaken at Sun Ship. The trial standards will serve as a strawman to test for possible industrywide concensus in this sensitive area. The standards are being selected to include representative forming, distortion, alignment, fitup, plate fairness, and weld profile tolerances. Source material for these standards includes foreign commercial shipbuilding industry standards, U.S. Navy and Maritime Administration standards, and standards from individual U.S. and foreign shipyards. The project is jointly funded by the U.S. Maritime Administration and Sun Ship under the National Shipbuilding Standards Program administered by Bath Iron Works. The trial standards will be reviewed by the SNAME SP-6 Panel and will be submitted to ASTM F 25.04 for consideration and possible adoption as an Industry standard, if a concensus proves possible.

HULL CONSTRUCTION TOLERANCE STANDARDS

Background

We might begin by asking what exactly are hull construction tolerance standards and what significance do they have. Hull construction tolerance standards are those standards which define the required dimensional accuracy of the various component pieces and operations encountered in hull construction. These include cutting and burning accuracy, weld bead size and shape, forming accuracy, distortion and fairness, end alignment and fit-up.

Hull construction accuracy affects hull structural performance in areas such as fatigue and stability. It also has an effect on hull resistance, particularly if plate surface roughness and coatings surface roughness are considered. Coatings performance, and alignment and operation of mechanical systems are other items which may be influenced by hull construction irregularities. Rough passageways and uneven deck plates are unfriendly or even hazardous for crew and cargo.

Construction tolerances also affect appearance. While this may not be the most crucial consideration, it can't be ignored.

Accuracy requirements have a significant impact on hull construction costs. Tighter tolerances often add to construction costs. Overly stringent tolerance standards are therefore to be avoided.

On the other hand, improved construction accuracy during fabrication has a significant favorable effect on the subsequent cost of erection. In some cases, the added cost of improving the dimensional accuracy of subassemblies may be more than recovered by reduced erection costs on the building ways.

Hull Construction Tolerance Standards Worldwide

In many of the more advanced shipbuilding nations, including Japan, Sweden and Germany, national industry-wide hull construction tolerance standards have been developed to some degree or another. The most extensive of these standards is the Japanese Shipbuilding Quality Standard (JSQS) published by the Society of Naval Architects of Japan. These standards were first issued in the mid-sixty's after deliberation among shipbuilders, classification societies, and others. The construction tolerances given in JSQS reflect extensive accuracy measurements taken over the years in Japanese shipyards.

The Japanese standards employ a two level system for tolerances. The first level, called the standard range, indicates the general level of accuracy considered satisfactory to ship owners and classification societies. It might be thought of as the target level of accuracy for the shipbuilding process. The second level of accuracy called the tolerance limit, indicates the level of accuracy within which individual corrective action is not generally required. This might be thought of as the limit of acceptability for individual pieces or assemblies.

In typical application, the standard range impacts process control. Isolated excursions beyond the standard range would not require action, while frequent excursions beyond the standard range might indicate a need for tighter process controls. On the other hand, the tolerance limit impacts the individual piece or assembly measured.

In statistical terms, the Japanese have found that only 5% of their measurements fell outside the standard range, and only .3% fall outside the tolerance limit. If we assume a normal distribution for the measurements, these figures indicate that the standard range corresponds to a

range of two standard deviations, and the tolerance limit corresponds to a range of three standard deviations.

Hull Construction Tolerance Standards in the U.S.

Presently no industry wide hull construction tolerance standards exist in this country despite the widely felt desirability of having such standards. One possibility for remedying this lack is for the shipbuilders to unilaterally prepare and issue tolerance standards, with the concurrence of regulatory agencies, through an organization such as SNAME. There are several drawbacks with this approach, not the least of which is the possibility of legal action relating to antitrust or restraint of trade legislation. Moreover, a unilateral action by shipbuilders, even if acceptable to classification societies, might not gain wide acceptance among ship owners. It was felt that another approach involving participation of all segments of OUR industry would be preferable.

The Present Project

The present hull construction tolerance standard project undertaken by Sun Ship is part of the MarAd sponsored National Shipbuilding Standards Program managed by Bath Iron Works and steered by the SNAME SP-6 Panel. As is typical of the projects in this program, the objective is to develop industry standards which can be approved and issued through ASTM - in particular through its Shipbuilding Committee F-25.

The ASTM is the largest voluntary consensus standards organization in the world. Their due process approval procedures involve producers, users and general interest groups. Because of the broad representation, and the due process approval procedures, ASTM has acquired an immunity to anti-trust action. For the same reasons ASTM standards generally enjoy a high level of acceptance.

Direction of the Project

The present effort is a small pilot project, designed to begin the standards development process in the area of hull construction tolerances. The project began with a review of existing standards, including foreign national standards (Japanese, Swedish, German), U.S. Navy and MarAd standards, and Ship Structure Committee report SSC 273. This last document is a survey which gives some insight into U.S. practice, but has no formal standing in the industry. Also included in our review were several shipyard standards where available (U.S. and foreign).

From the existing standards, some 40 items were selected for the present project. These are individual standards which were thought to be reasonable and representative. Ihe candidate standards were drawn from various of the sources listed above, and covered a variety of construction operations. The standards selected are intended to serve as a "strawman" - in other words trial standards to test for possible consensus. It is possible that achieving consensus will be difficult in this sensitive area. Shipbuilders and owners are likely to begin the process with somewhat different viewpoints, and consensus may be difficult in areas where subjective judgments and divergent interests are involved. The present effort should serve to point up problem areas in this regard and the results should serve as a nucleus for an ongoing standards development effort in this area.

The candidate standards were not chosen expressly on the basis of fitness-for-purpose, but it is expected that there is a relationship between the candidate standards and acceptable performance. The JSQS standards for example reflect actual Japanese shipbuilding experience and therefore these standards are generally relatable to the performance of Japanese ships constructed in that period. Other standards reflect analytical or experimental

work, or reflect the judgment and experience of knowledgeable practitioners.

Form of Proposed Standards

The organization of the present effort is outlined in Figure 1. The contents were selected to cover a representative cross section of the types of construction tolerances encountered in practice. Some specific examples of proposed construction tolerance standards are shown in Figures 2 through 7. Where appropriate, the standards include a two level system for tolerances, namely standard range and tolerance limit, as in the JSQS.

Figure 2 shows proposed tolerance standards for flange breadth and straightness, for flanged plate longitudinals. These standards reflect U.S. practice, per SSC 273, and are *also* comparable to JSQS standards.

Figure 3 shows proposed alignment standards for lateral alignment of flanges in longitudinals, and for alignment of intercostal joints. The first reflects Swedish shipbuilding standards, and the latter is a first cut for discussion in an area where there is presently a divergence among existing standards.

Figure 4 shows the proposed standard for fairness of critical hull plating. This standard is taken directly from the MarAd fairness specification and does not differ greatly from the corresponding Navy specification. The indicated tolerances are interpreted as tolerance limits.

Figure 5 shows proposed standards for local dents and weld depressions, again interpreted as tolerance limits. These standards are derived from the German shipbuilding standards.

Figure 6 shows proposed distortion tolerances for besms, frames, girders, and stiffeners. The standard range and tolerance limits shown are derived from the JSQS, and are consistent with the German Standards.

Figure 7 shows a proposed tolerance standard for stanchion straightness. The indicated standard range and tolerance limit are taken from the JSQS.

Remarks

In the present effort we define the standard range to be the level of construction accuracy which is normally expected to be achieved using conventional shipbuilding practice. The tolerance limit in the present effort is defined as the construction tolerance range within which no remedial action need be taken for the item in question. Construction inaccuracys falling outside the standard range, but within the tolerance limit, generally require no remedial action with respect to the element in question. However, if such inaccuracys are encountered frequently, it may indicate that processes controls should be reviewed and possibly tightened. Construction inaccuracys falling outside the tolerance limits may cause problems in service or at subsequent stages of construction and generally require remedial action.

The present candidate standards have been submitted to the SNAME SP-6 Panel for review and comment prior to their submission later this year to the ASTM Shipbuilding Committee F-25.

Where appropriate, standard corrective actions will also be indicated. It may not always be possible to identify a preferred all purpose corrective action. In many cases, the best course of action will depend on individual circumstances.

The proposed standards are intended to serve as a practical guideline for hull construction tolerances - a further clarification of U.S. practice. They would also be available to draw from if owner and builder agreed to make more binding arrangements regarding construction tolerances.

FIGURE 1

ORGANIZATION OF SELECTED STANDARDS

WELDING

- SHAPE OF BEAD

FABRICATION AND FORMING

- FLANGED PLATE LONGITUDINALS
- FLANGED BRACKETS
- BUILT-UP SECTIONS
- PLATES

ALIGNMENT AND FITTING

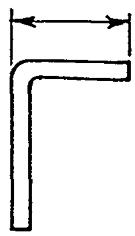
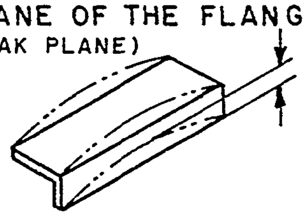
- FITTING ACCURACY
- OPENINGS

DISTORTION AND FAIRNESS

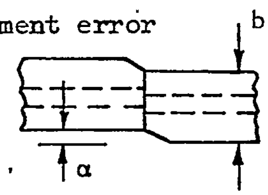
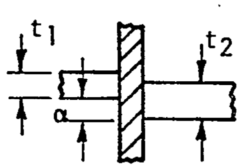
- FAIRNESS
- LOCAL DENTS AND WELD DEPRESSIONS
- DISTORTION OF HULL FORM
- MISCELLANEOUS

FIGURE 2

B. FABRICATION & FORMING

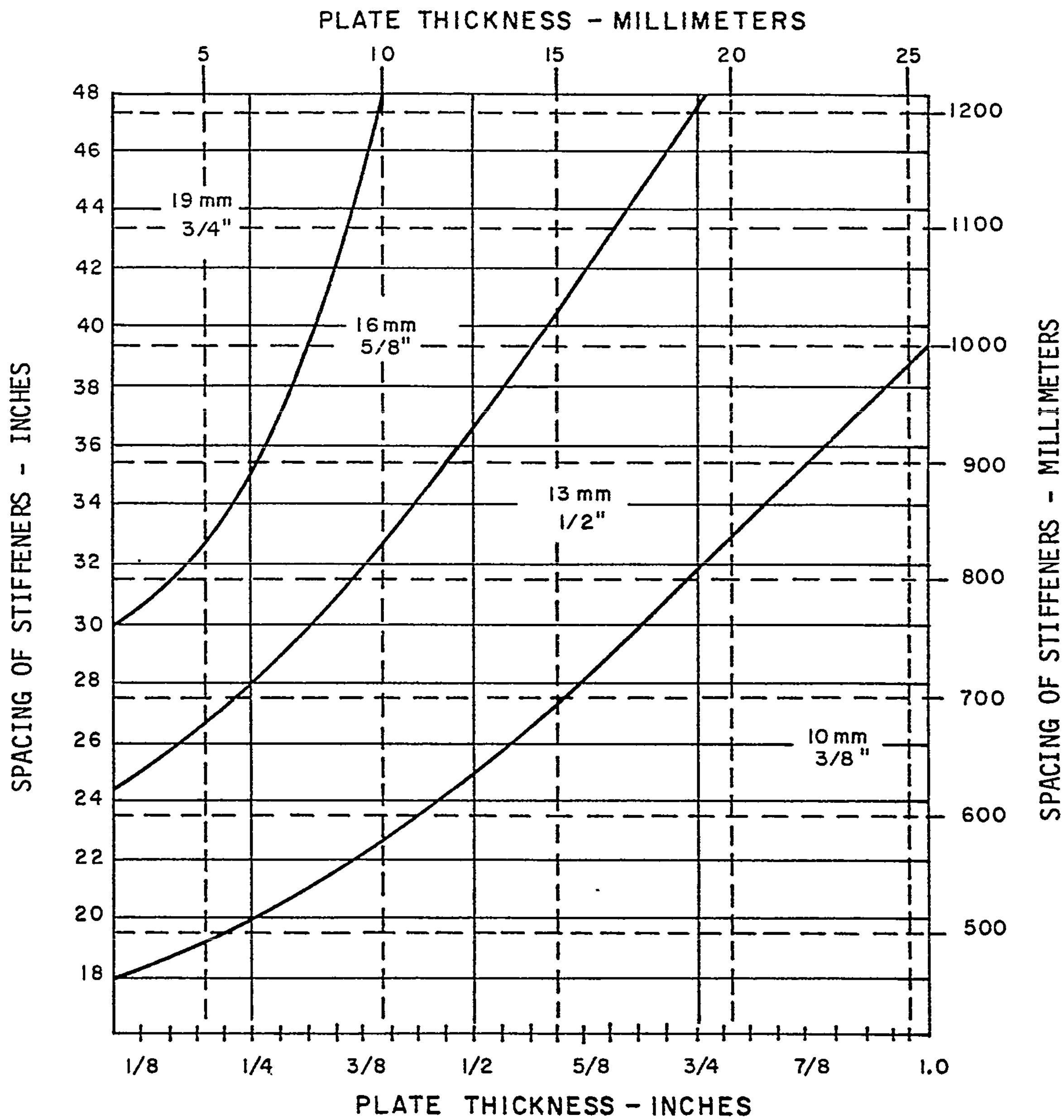
B-1 FLANGED PLATE LONGITUDINAL	STANDARD RANGE	TOLERANCE LIMITS
B-1.1 BREADTH OF FLANGE 	± 1/8"	± 1/4"
B-1.4 CURVATURE OR STRAIGHTNESS IN THE PLANE OF THE FLANGE (WEAK PLANE)  Per 400 inches in length	±3/8"	±1"

C. ALIGNMENT & FITTING

C-1 FITTING ACCURACY	STANDARD RANGE	TOLERANCE LIMITS
C-1.1 FLANGE IN TEE LONGITUDINALS Alignment error  Alignment of webs must meet standard for alignment of butt joints.		$\alpha \leq .04b$ (Max. 5/16")
C-1.2 ALIGNMENT OF FILLET JOINT Strength Member  α: DIFFERENCE t = THICKNESS $t_1 \leq t_2$ Other		$\alpha \leq \frac{t_1}{2}$ But not to exceed weld size $\alpha < \frac{t_1}{2}$

D- I. 1.2 **FIGURE - 2**

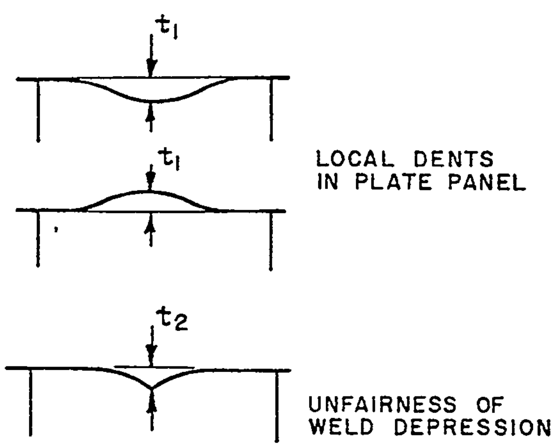
THIS FIGURE DOES NOT APPLY FOR LOCAL DENTS OR WELD DEPRESSIONS. REFER TO SECTION D-2 FOR THOSE CONDITIONS.



This figure is applicable for the following areas:

1. Entire shell.
2. Upper most strength deck.
3. Longitudinal strength structure within the Midship 3/5 length which includes inner bottom tank top.

D. DISTORTION & FAIRNESS



D-2 LOCAL DENTS AND WELD DEPRESSIONS		DEPTH t_1	DEPTH t_2
D-2.1 SHELL	ABOVE WATERLINE	5/16"	3/8 "
	BELOW WATERLINE	5/16	1/2
D-2.2. MAIN DK	FREE AREA	1/4	3/8
	COVERED AREA	3/8	

FIGURE 6

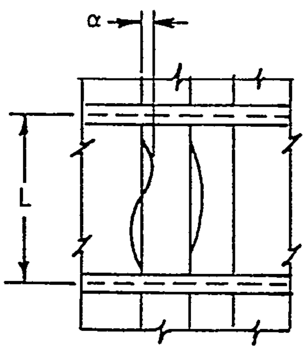
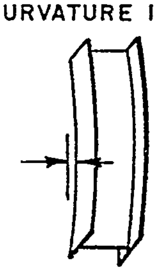
D-4.1. PERMISSIBLE DISTORTION OF BEAMS, FRAMES, GIRDERS AND STIFFENERS. Deviation from straight line between 2 points of support. 		
$L < 30''$	$\alpha \leq 3/16''$	$\alpha \leq 5/16''$
$30'' \leq L \leq 125''$	$\alpha \leq \frac{L}{500} + 1/8''$	$\alpha \leq \frac{L}{500} + 1/4''$
$L > 125''$	$\alpha \leq 3/8''$	$\alpha \leq 1/2''$

FIGURE 7

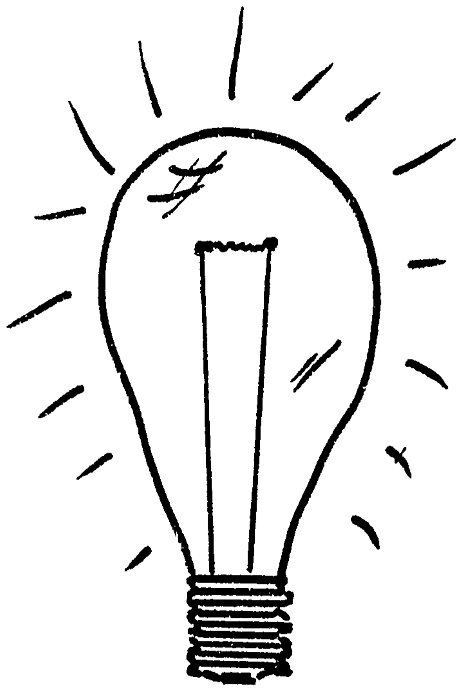
D-4.5. DISTORTION OF 'H' PILLAR BETWEEN DECKS. CURVATURE IN EITHER PLANE.  TYPICAL LENGTH 10 FT.	3/16"	1/4"

THE IPD SYSTEM FOR INTERACTIVE PART CODING AND NESTING

Richard C. Moore
Manager, Computer Design Department
Newport News Shipbuilding and Dry Dock Company
Newport News, Virginia

Mr. Moore is responsible for development and implementation of computer aided design techniques. Primary areas of interest are structural and piping design where computer aided manufacturing systems are already in operation. He is also IPD project manager.

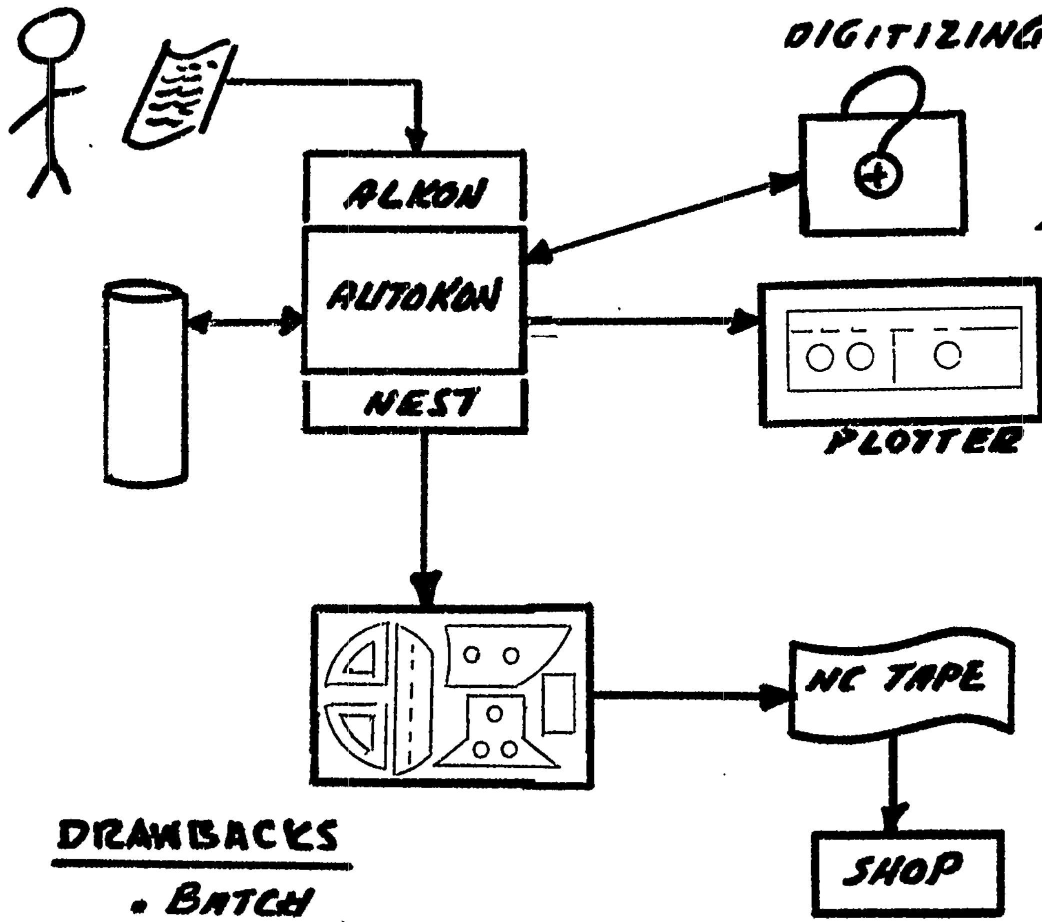
Mr. Moore holds degrees in naval architecture and marine engineering from the University of Michigan. He has 15 years of experience in structural production work including management responsibility in mold loft, fabrication, and assembly areas. Also implementation of computer systems for numerical control lofting/cutting, structural work packages.

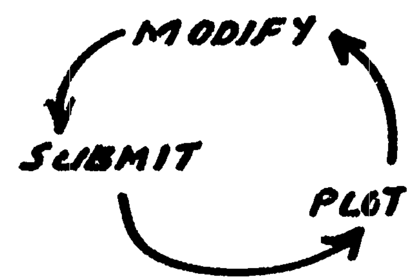


1975 IDEA

INTERACTIVE PARTS DEFINITION

MOLD LOFT
CURRENT TECHINQUES



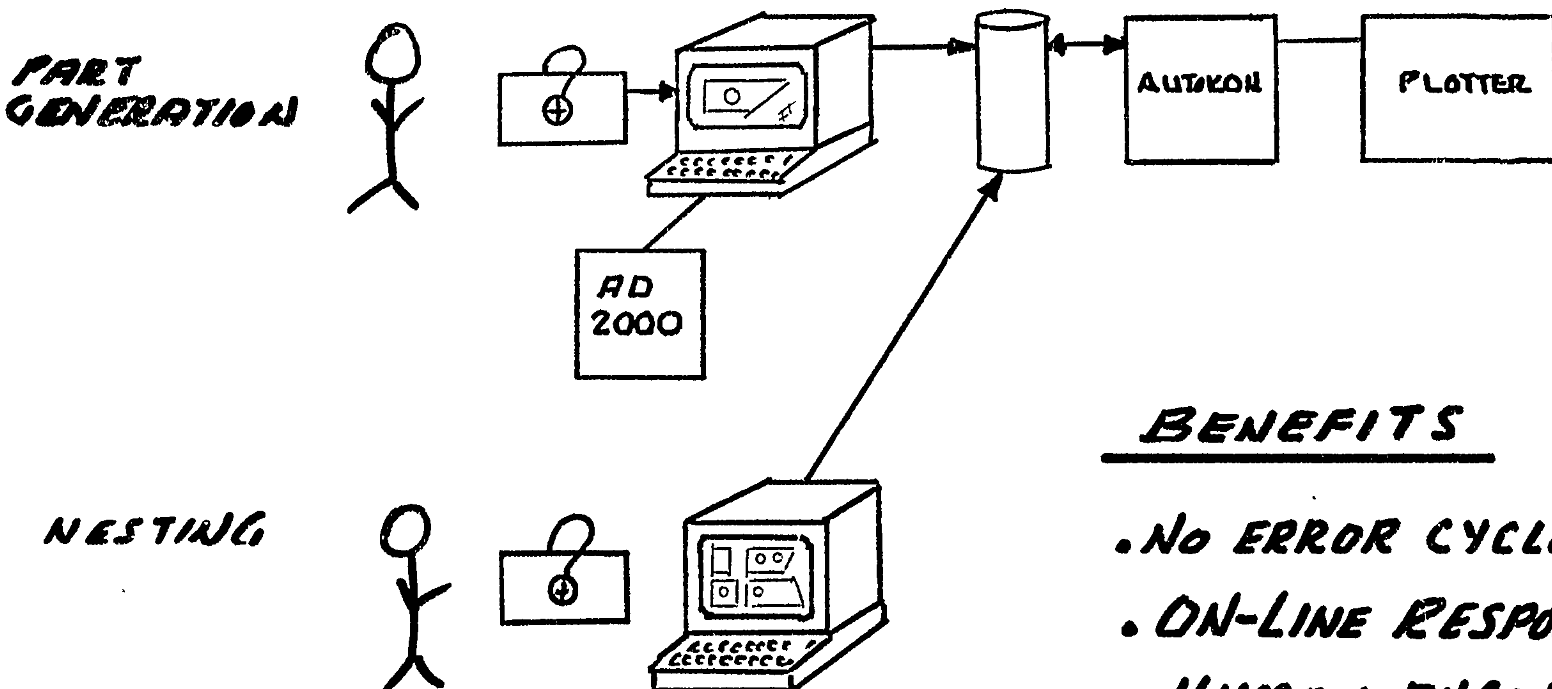


DRAWBACKS

- BATCH
- CORRECTION CYCLE
- TRAINING
- HUMAN ENGINEERING

MOLD LOFT

PROPOSAL



BENEFITS

- NO ERROR CYCLE
- ON-LINE RESPONSE
- HUMAN ENGINEERING

INTERACTIVE GRAPHICS PART DEFINITION PROJECT

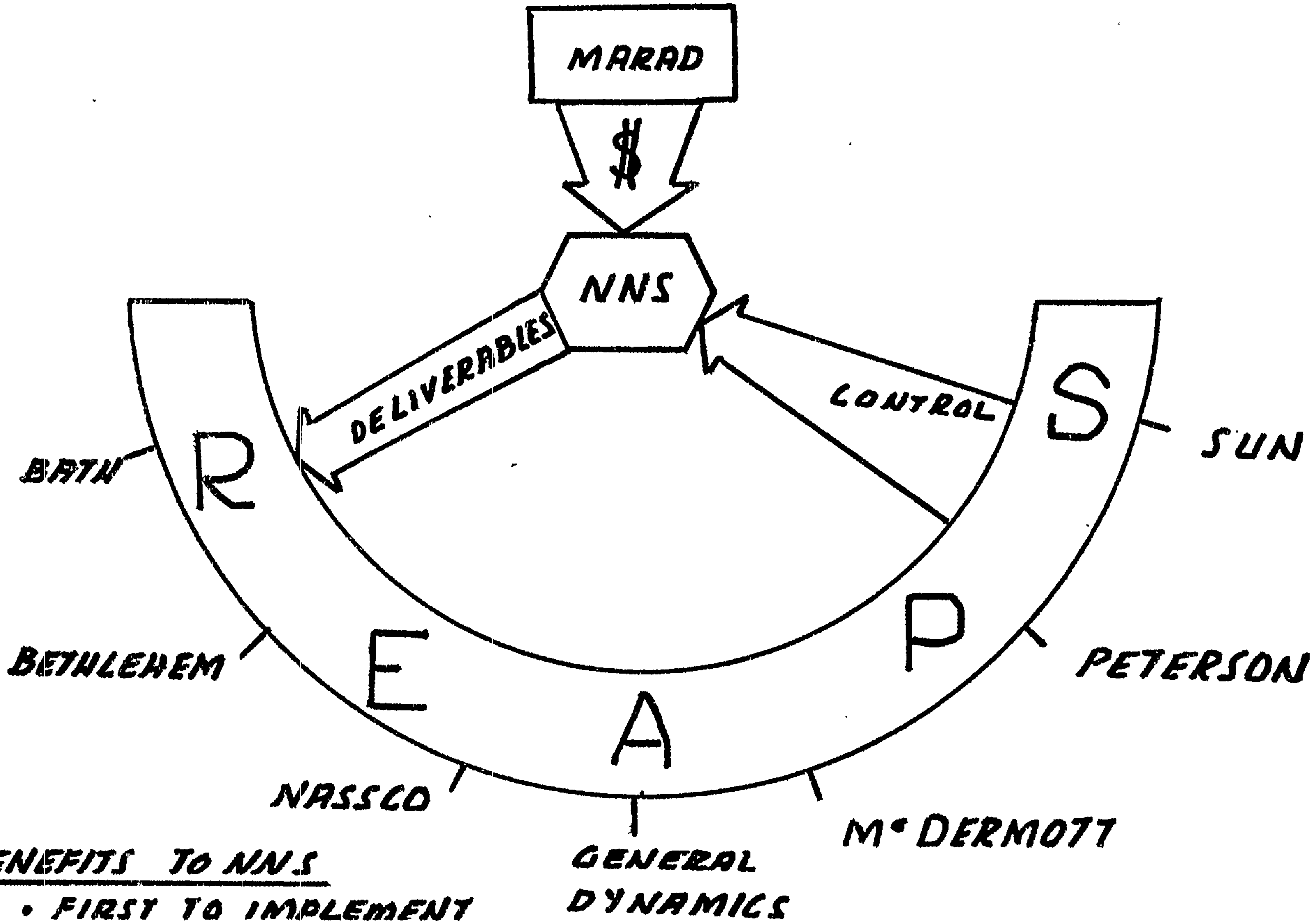
MAIN REQUIREMENTS OF IPD AS DEFINED BY NNS AND REAPS TECH REPS,

- HARDWARE/SOFTWARE PACKAGE TO.ALLOW.USERS TO PERFORM REAL TIME DEFINITION OF THEIR APPLICATION WITH VISUAL (GRAPHIC) OUTPUT AND BUILD UP A DIGITAL MODEL.OF THE DEFINITION AT THE SAME TIME,
- MUST BE PORTABLE AND CAPABLE OF BEING UPDATED AND EXPANDED INDEPENDENTLY OF THE VENDOR,
- PROVIDE A GENERAL TOOL TO BE AVAILABLE FOR FUTURE GRAPHICS PROJECTS WITHIN U,S, SHIPBUILDING, -
- DEDICATED COMPUTER,HARDWARE TO PROVIDE RESPONSE.TO SUPPORT INTERACTIVE GRAPHICS,
- CAPABL OF DIRECT INTERFACE TO AUTOKON/ SPADES7STEERBEAR SYSTEMS,

FUNCTIONAL AREAS ADDRESSED BY IPD

- STRUCTURAL PART DEFINITION (CURRENT LOFTING)
- NESTING
- STRUCTURAL SHOP DRAWINGS
- Nc MACHINING (APT)
- DESIGN USE

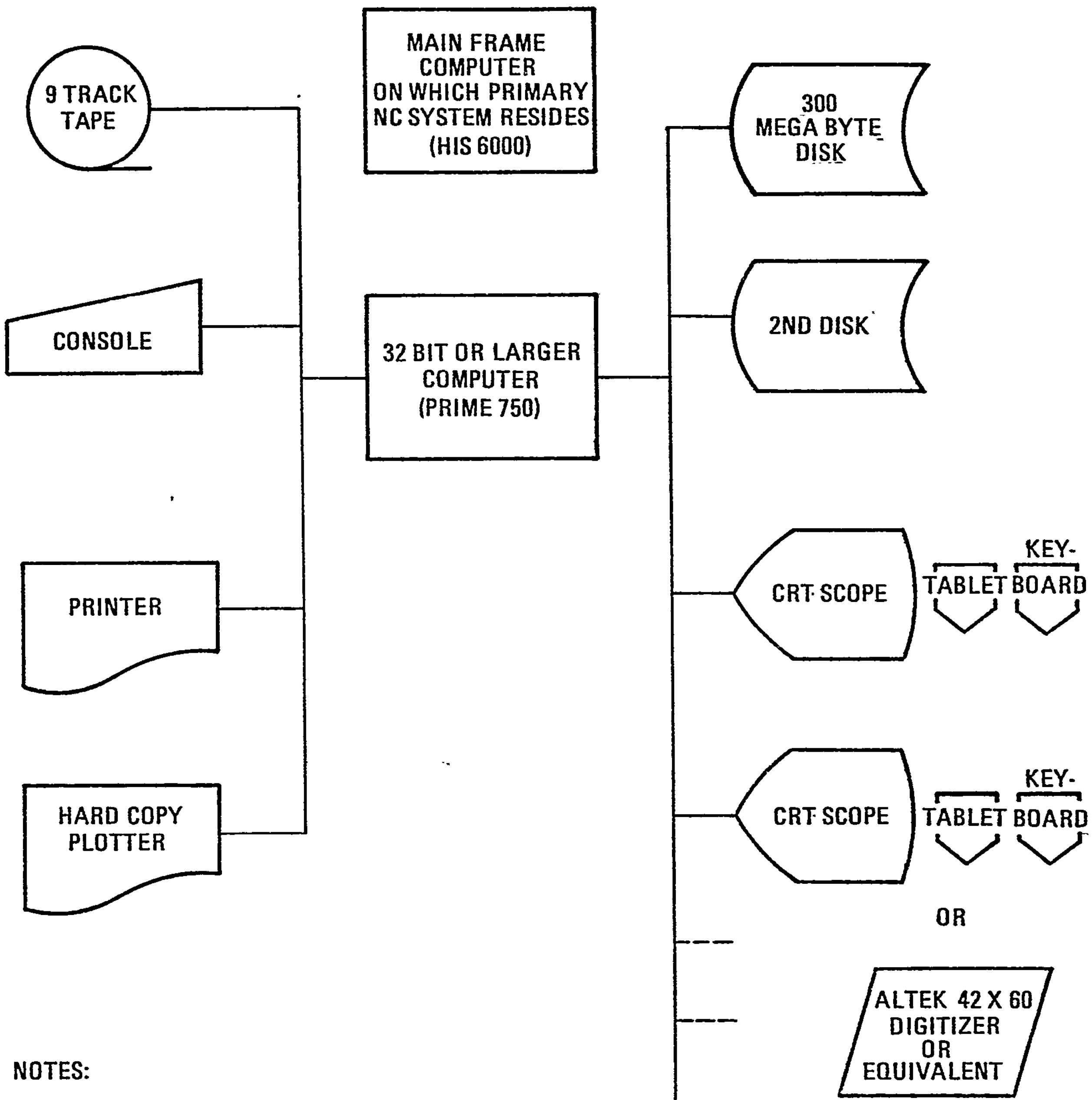
SECONDARY-EVENTS AT NNS



BENEFITS TO NNS

- FIRST TO IMPLEMENT
- DEVELOPMENT FUNDS
- EXPERTISE GAINED

HARDWARE CONFIGURATION

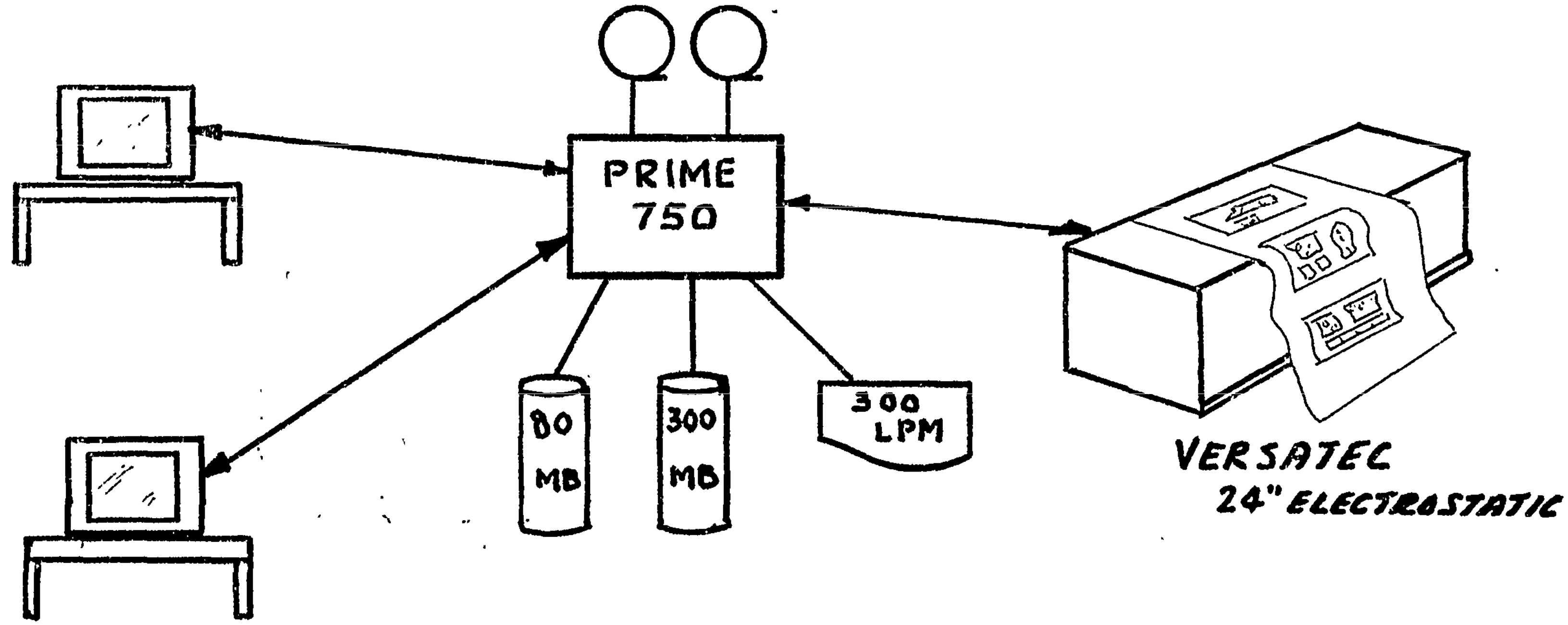


NOTES:

CRT WILL BE SEMI-REFRESH TO ACCOMPLISH NESTING AT A PRODUCTIVE RATE.

POSSIBLE PAPER TAPE READER/PUNCH REQUIREMENT.

IPD HARDWARE MODULES



TEKTRONIX 4081

- LOCAL INTELLIGENCE
- SEMI REFRESH
- TABLET

REJECT	YES	OPERATION COMPLETE	NO	REPAINT	DEPTH	CANON	

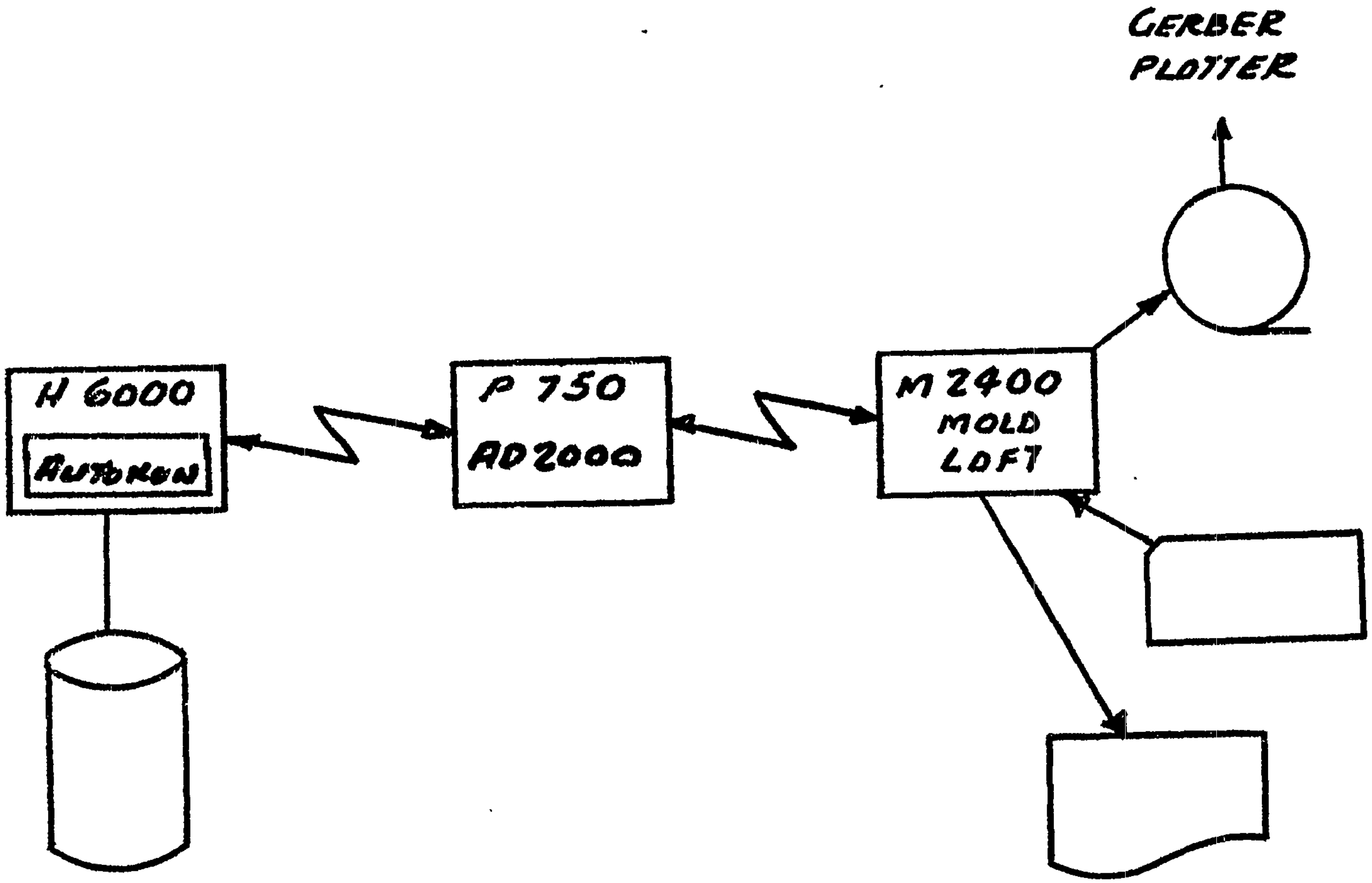
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
U	V	W	X	Y	Z					0	1	2	3	4	5	6	7
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
.	+	,	–	=	!	"	#	$	%	:	;	*	(	)	'	&	

RETURN TO ORIGINAL SCALE	SELECT A NEW CENTER	NEW CENTER KEY-IN SCALE	DOUBLE SCALE	HALF SCALE	ALL POINTS	FROM TYPES	FROM ALL	LAST ENTITY CREATED
Z O O M					D E L E T E			
KEY-IN SCALE	DIAGONAL POINTS	KEY-IN MAX-MINS	AUTO MAX-MINS	SAVE ZOOM STATUS	ALL NOT DISPLAYED	ALL OF A DISPLAYED TYPE	ALL OF A TYPE NOT DISPLAYED	ALL OF A LEVEL

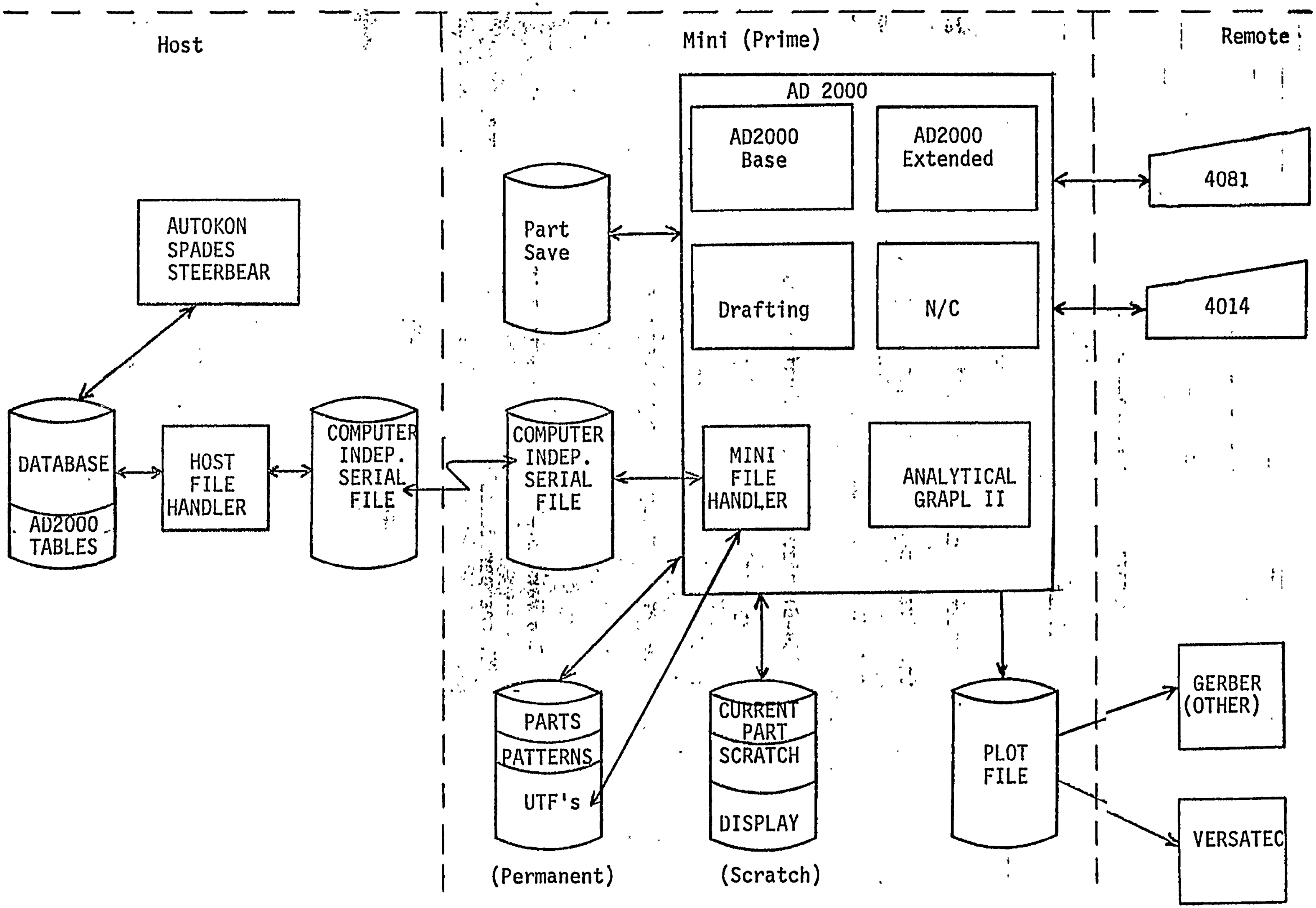
ENTITY TYPES →	POINT	LINE	ARC/ CIRCLE	CONIC	SPLINE	OTHER CURVES	GROUP AND ARRAY	EXT. GEOM. CURVE	SURFACE	LABEL AND NOTE	DIMEN.	CENTER LINE	CROSS HATCH

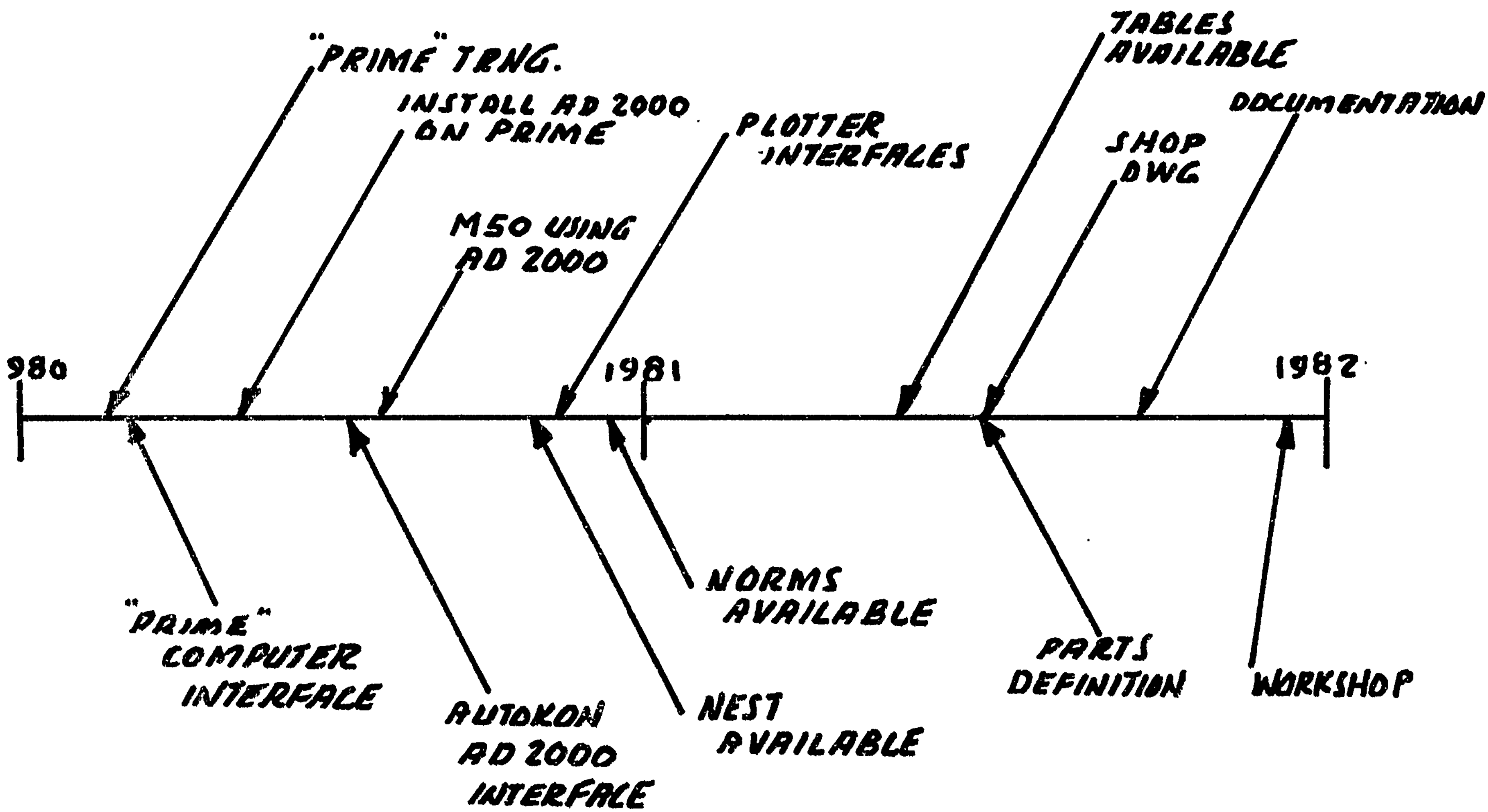
DISPLAY TOLERANCE	SYSTEM DECIMAL PLACES	CHANGE CURVE FONT	MODIFY ENTITY LEVEL, FONT, OR PEN NO.	CONTROL SURFACE PATHS	CHANGE CURSOR MODE	CONTROL VIEW VECTORS	SEQ. NO./ POINTER SELECT	DISPLAY TITLE BLOCK
B L A N K						U N B L A		
ALL OF A TYPE	ALL EXCEPT A TYPE	ALL	SELECT FROM TYPE	SELECT FROM ALL	LEVELS	ALL	ALL OF A TYPE	ALL EXCEPT A TYPE
SCREEN POSITION	XT: YT: ZT: KEY-IN	R ANGLE POLAR	DX DY DELTA	CIRCLE CENTER	ON A CIRCLE AT AN ANGLE	SCREEN POSITION	X1: Y1: Z1: X2: Y2: Z2: KEY-IN	JOIN 2 POINT
CURVE ENDPOINT	INTERSECTION OF TWO CURVES	DS VECTORED	REGENERATE SPLINE POINTS	ON A LINE AT A COORDINATE	CURVE NORMAL	THRU POINT HORIZ/VERT	THRU POINT TANTO CURVE	PARLEL TO LINE AT A DISTANCE

INTERFACES



IPD Software Modules

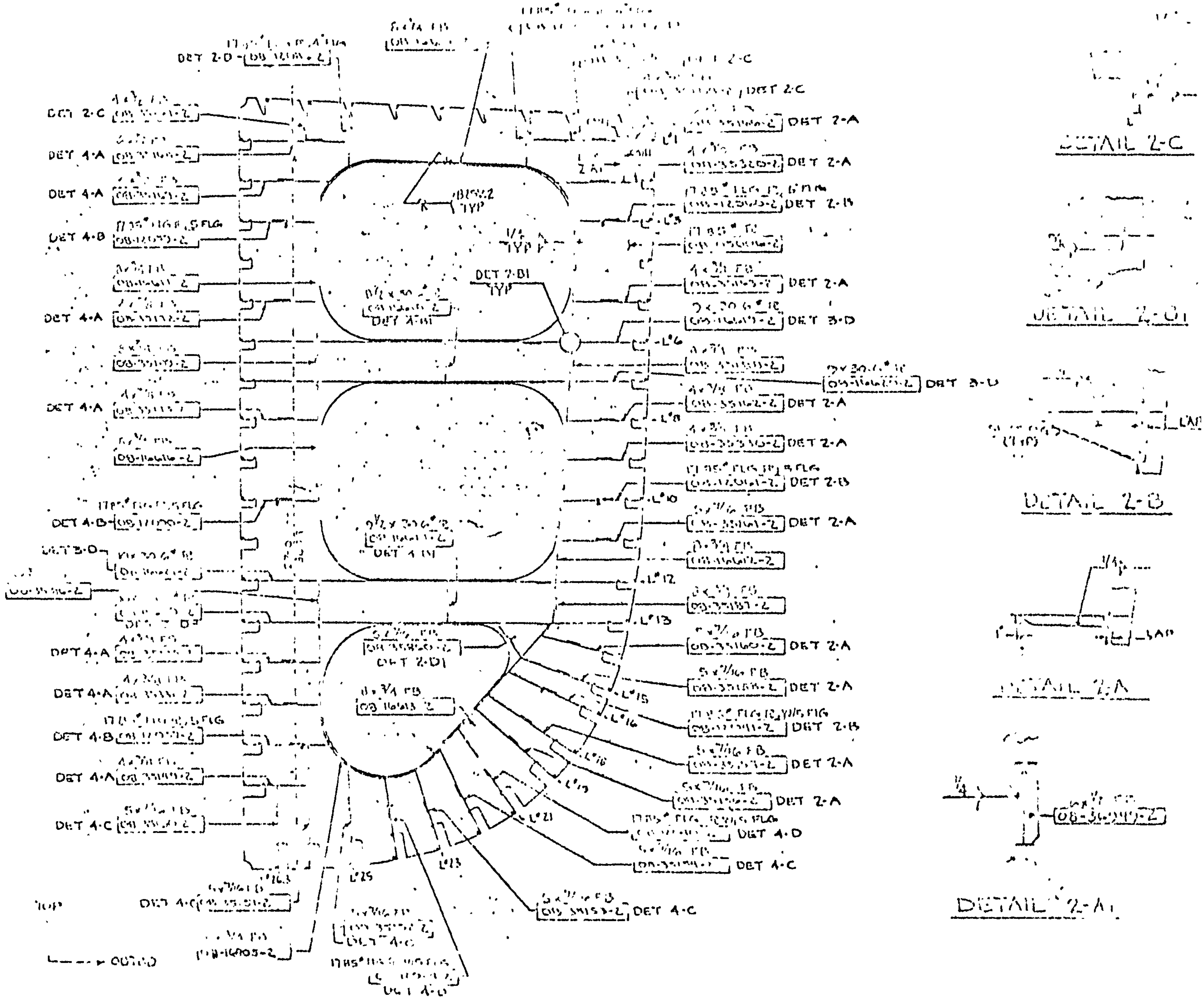



"PRIME" TRNG.
INSTALL AD 2000 ON PRIME
M50 USING AD 2000
PLOTTER INTERFACES
TABLES AVAILABLE
SHOP DWG
DOCUMENTATION
980
1981
1982
"PRIME" COMPUTER INTERFACE
AUTOKON AD 2000 INTERFACE
NEST AVAILABLE
NORMS AVAILABLE
PARTS DEFINITION
WORKSHOP

PROJECT PLAN
PHASE II

	MONTH OF COMPLETION FROM START OF PHASE
* • ISSUE PURCHASE ORDERS	1
* • PRIME TRAINING	3
* • DEFINE DATA SPECIFICATION	5
* • AD 2000 INTERFACE	5
* • WRITE HOST ROUTINES	7
* • HARDWARE/SOFTWARE INSTALLATION	7
* • RJE INTERFACE	7
* • AD 2000 INSTALLATION	9
• AD 2000 TRAINING	10
* • MINI SEND/RECEIVE	12
• REFINE NEST	20
• REFINE NORMS	15
• TABLES	19
• SHOP DRAWING CAPABILITY	20
• REFINE PARTS DEFINITION	20
• DOCUMENTATION	23
• WORKSHOP	24

*INDICATES WORK ALREADY COMPLETE


DET 2-D
DET 2-C
DET 4-A
DET 4-B
DET 3-D
DET 4-C
DET 2-A
DET 2-B
DET 3-D
DET 4-D
DET 2-B1
TYP
DET 2-D1
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DETAIL 2-A
DETAIL 2-A1

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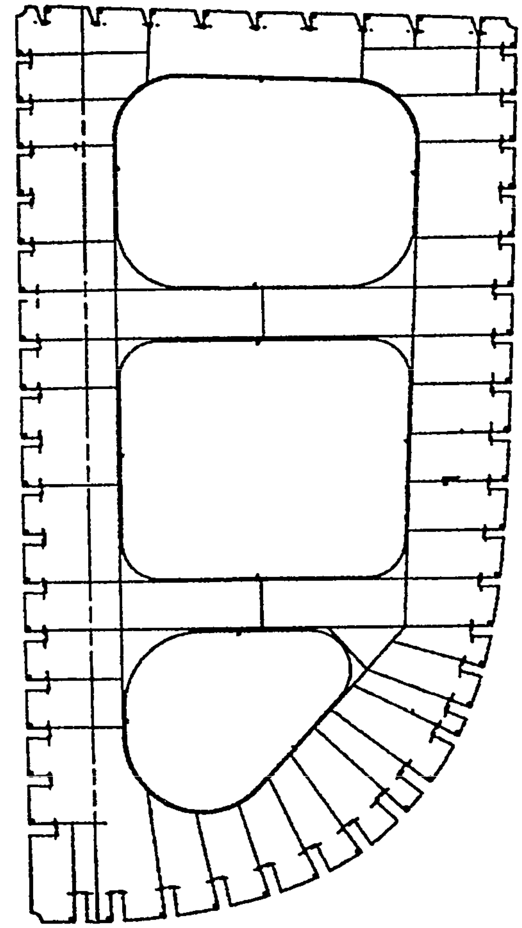

MODIFY LEVEL/PEN NO.

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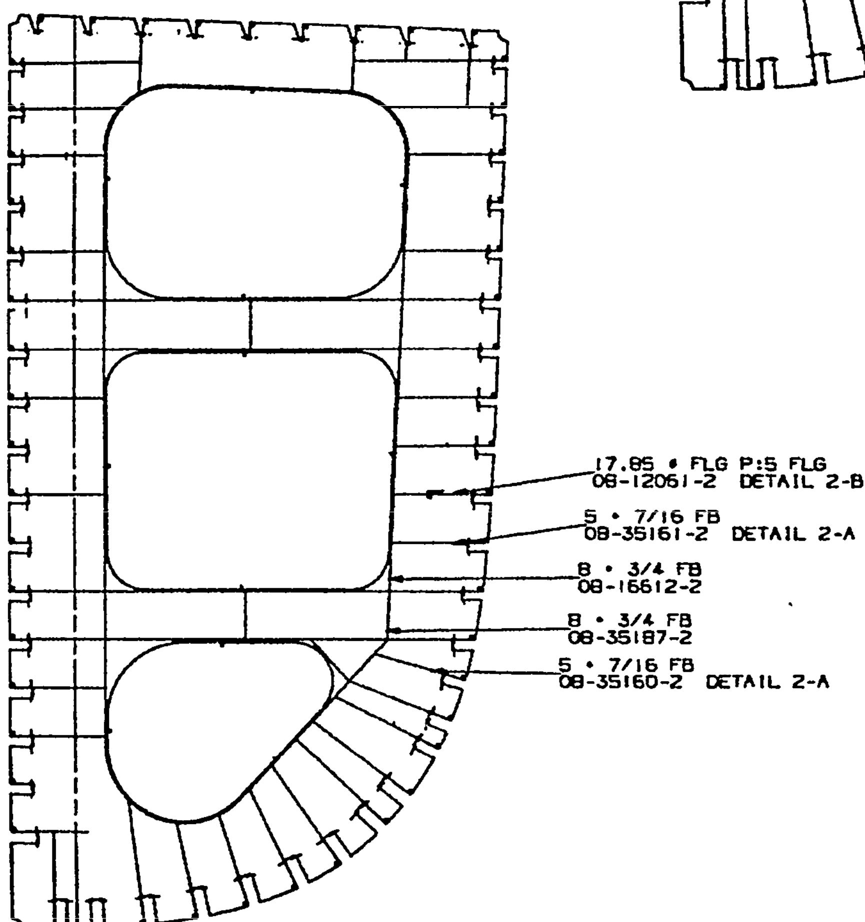

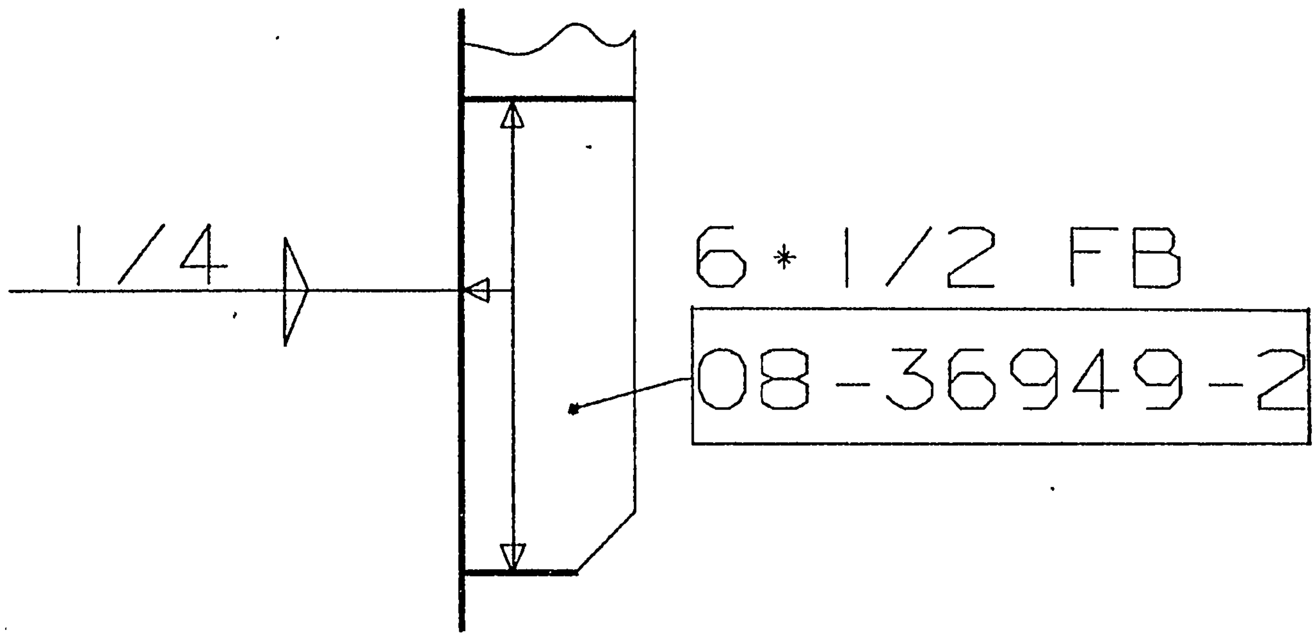

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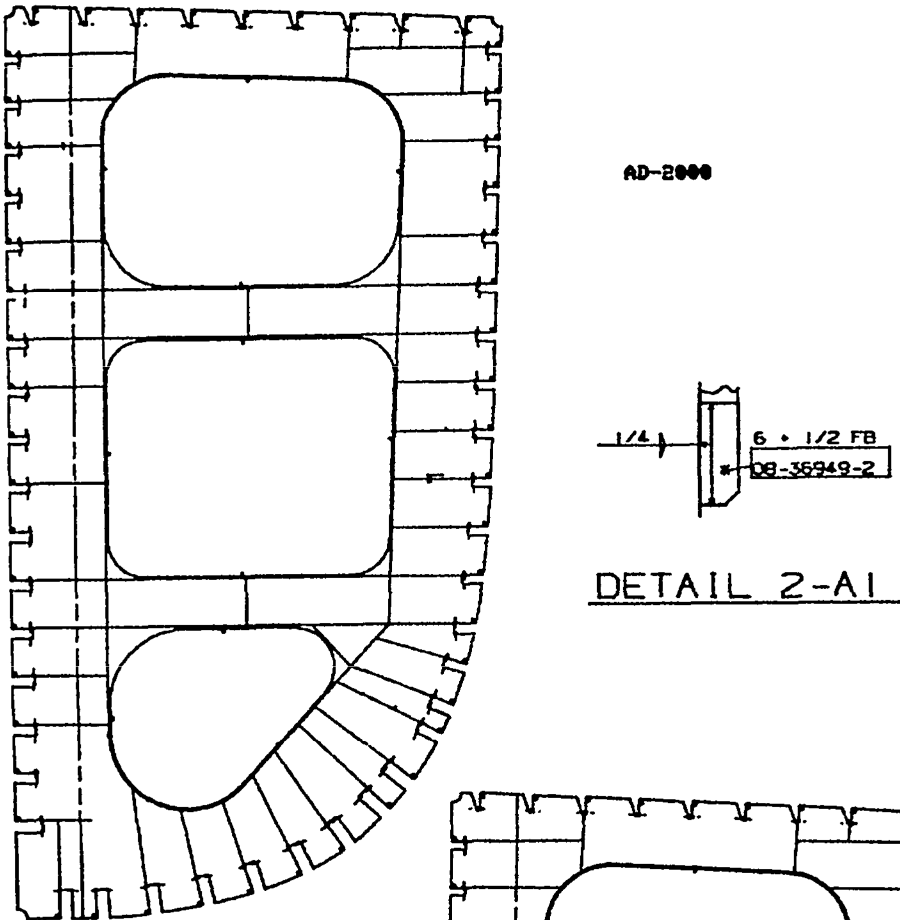
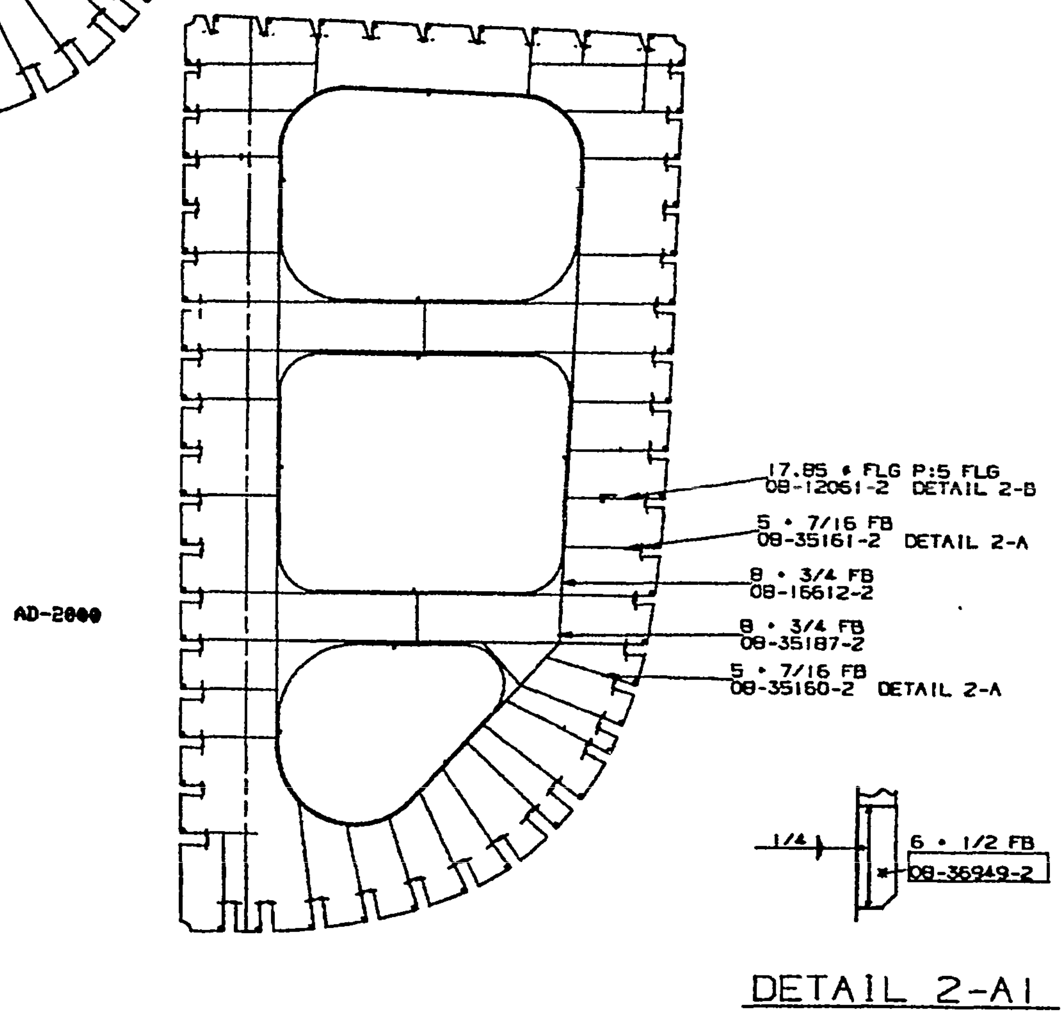

AD-2000
1/4
6 • 1/2 FB
08-36949-2
DETAIL 2-A1


AD-2000
17.85 • FLG P:5 FLG
08-12061-2 DETAIL 2-B
5 • 7/16 FB
08-35161-2 DETAIL 2-A
8 • 3/4 FB
08-16612-2
8 • 3/4 FB
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5 • 7/16 FB
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1/4
6 • 1/2 FB
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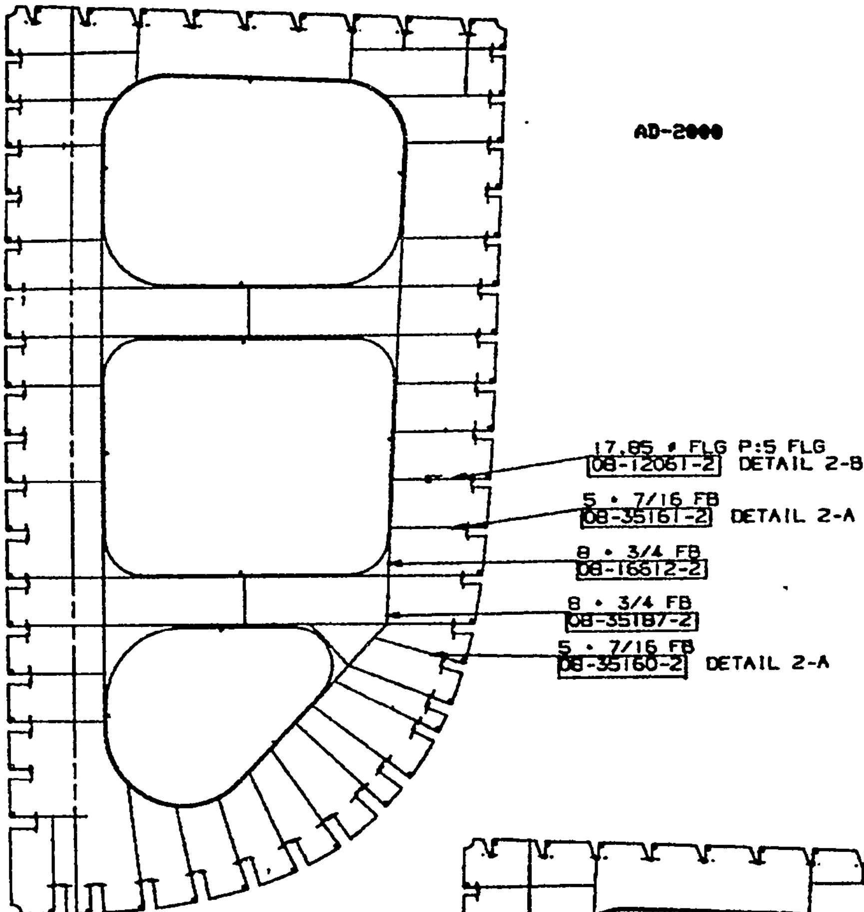
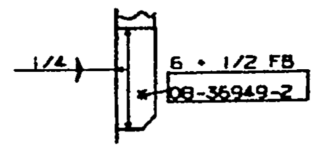
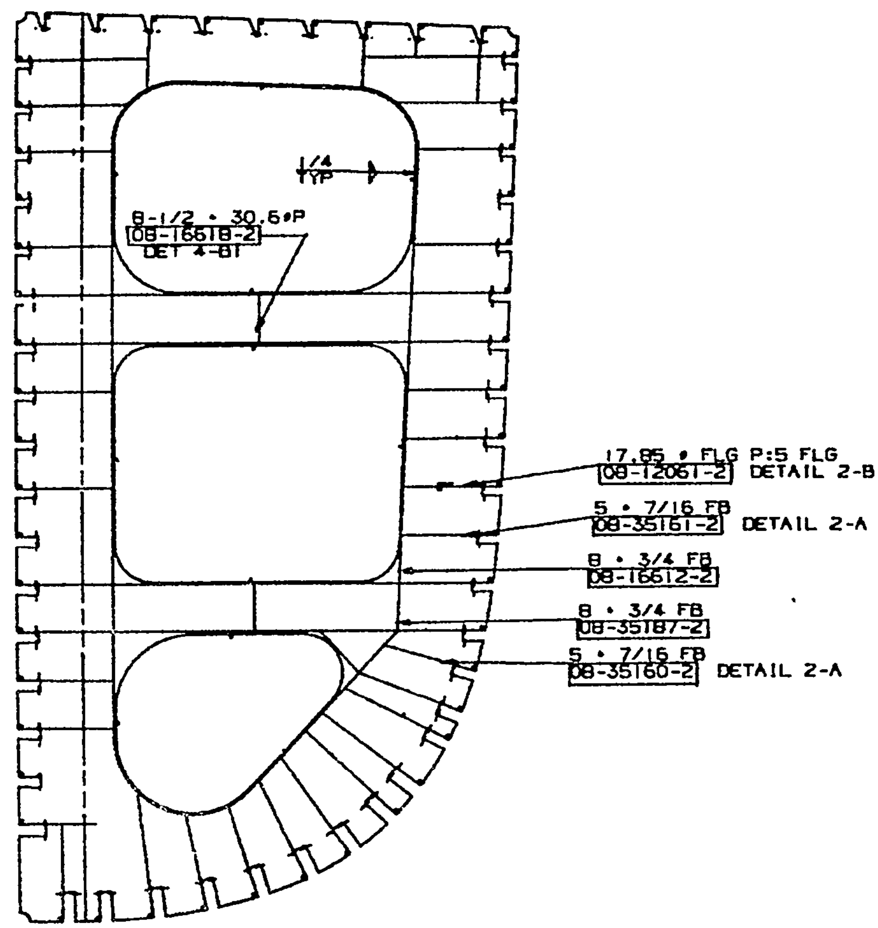
DETAIL 2-A1

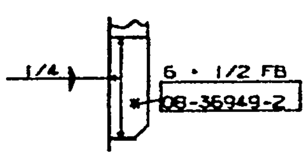




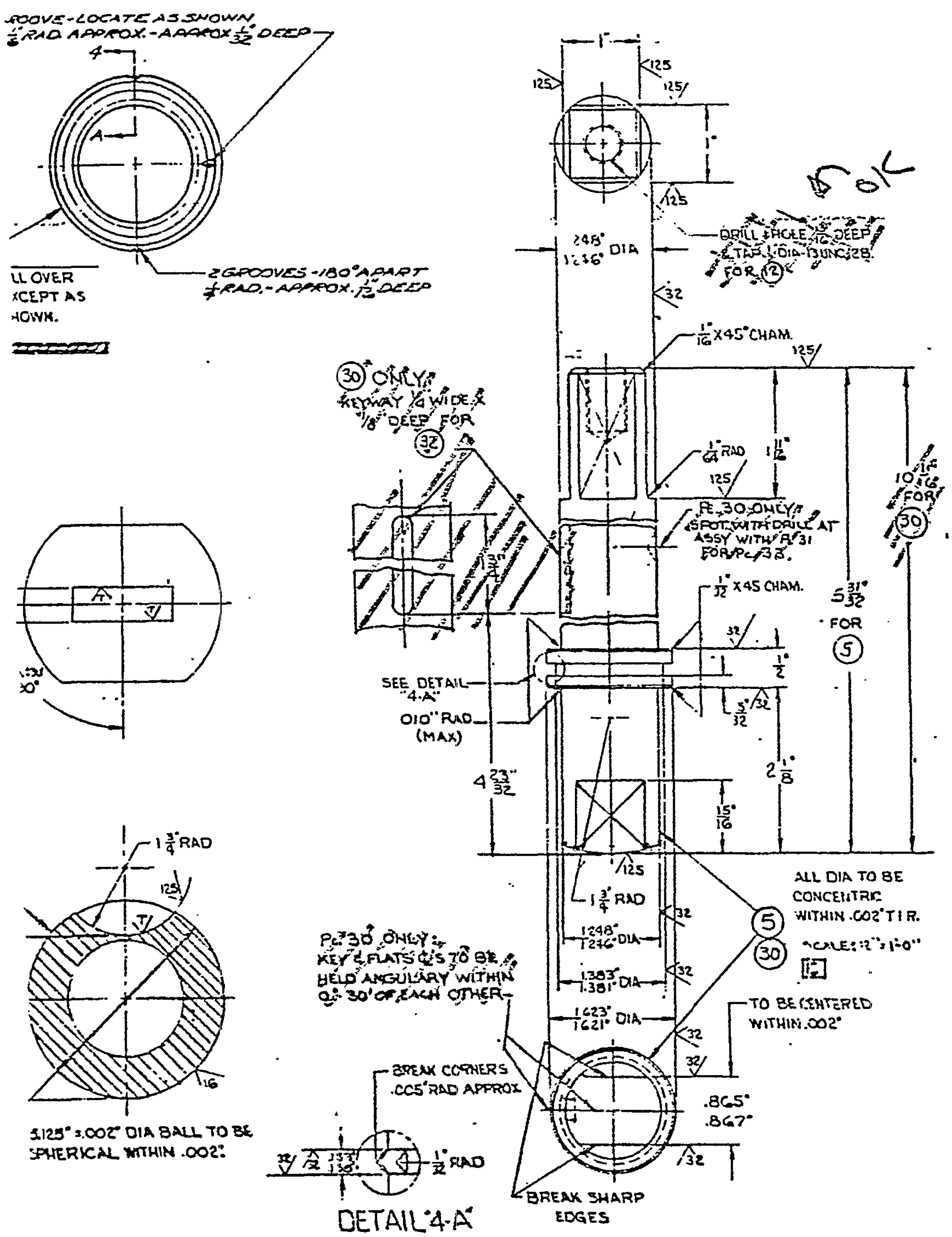
DETAIL 2-A1

AD-2000





DETAIL 2-A1



ALL DIA TO BE CONCENTRIC WITHIN .002" T I R.
DETAIL "4-A"
SCALE: 24"=1'-0"
BREAK SHARP EDGES
BREAK CORNERS .005" RAD APPROX.
TO BE CENTERED WITHIN .002"
SEE DETAIL "4-A"
.010" RAD (MAX)
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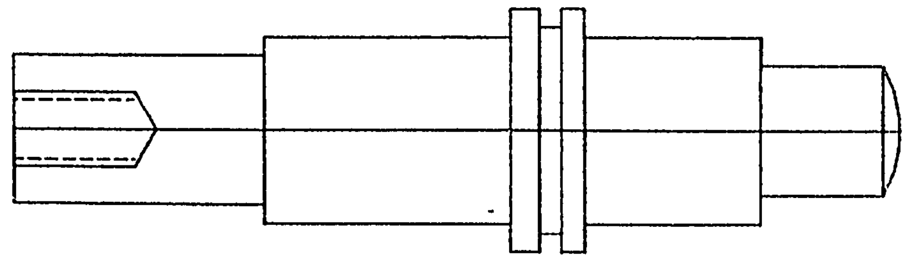
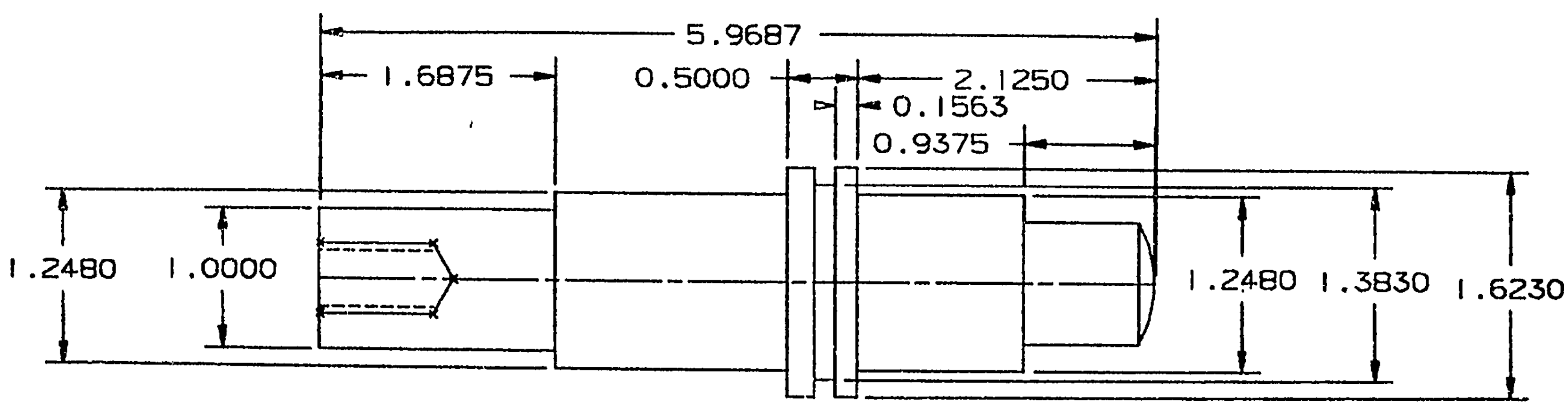


LEVEL MANAGEMENT

LISTING FOR 'STEM

0. DRAWING SPACE
1. TURNING GEOMETRY
2. MILLING GEOMETRY
3. DIMENSIONS
4. NOTES
5. GEOMETRY POINTS

~~HIT YES OR NO TO CONTINUE Y~~
LEVEL MANAGEMENT



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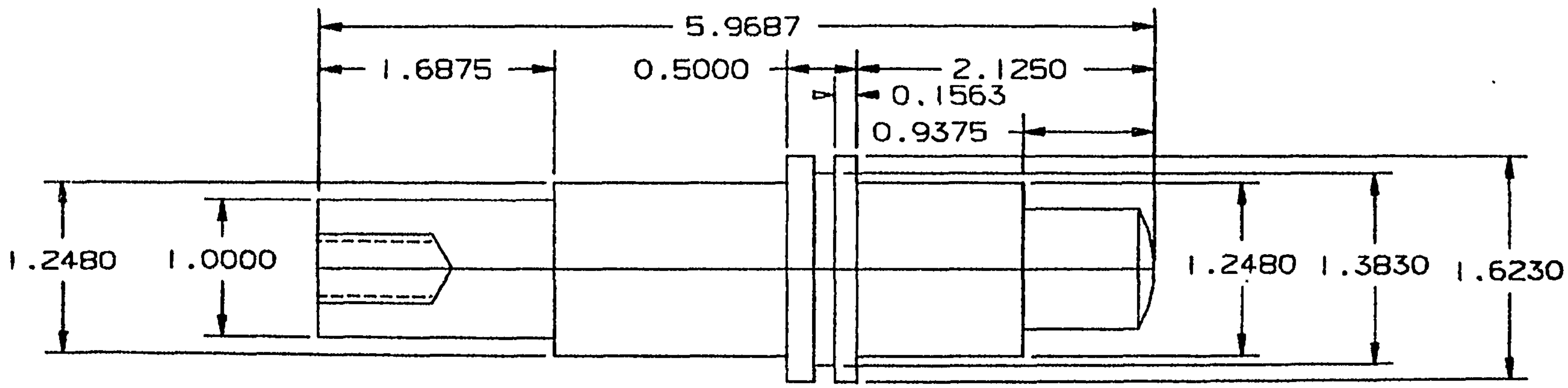

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SHIPYARD PLANNING AND THE COMPUTER: FACT OR FANTASY

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ABSTRACT

The planning environment in American shipyards has undergone a change of technique and attitude with the upswing in use of computers. Traditional planning mechanisms have given way to PERT networks and sophisticated data collection and reporting computer systems. This transition has not been as successful as was intended, as evidenced by the planning and scheduling problems faced by many of these computerized yards.

Data processing was moved from the basic accounting arena into operations research and massive production-oriented systems which has diluted the planning effort. This is caused by planners which have not evolved from production, a planning attitude that the computer can solve all problems, and management's inability to recognize the shortcomings of computer software. Technology is available to assist the shipyard with total planning and complete ship's plans and schedules. However planning, in itself, must be adapted to use this computer technology and not be driven by it.

These topics are addressed: (1) An analysis of traditional planning techniques; (2) An evaluation of data processing in the planning environment; (3) A critique of the computerized planner; (4) Recommendations for management, planning, and data processing to improve the problem areas of computers in planning.

The Planning environment of American shipyards has witnessed a noticeable change with the advent of the high-speed digital computer. The tedious laboring of the pianners has given way, in part, to the sophistication of the computer and its software. While in no way does the machine intend to replace the planner, it has altered, considerably, the attitudes, methodology, and results of the planning department. This marriage, however, does not go well.

Traditional planning techniques are difficult to define since each shipyard is subject to the talents and experience of its staff. Planning and scheduling does not have a long history of formalized background, such as Engineering, and therefore, cannot be classified as to methodology, whether good or bad. Manual planning takes whatever form was first invented and subsequently modified by time and differing planning personnel. Any planning standard which may exist is merely a fallout of personnel movement from yard to yard, and defined by the type of ships being built. Planning discipline within the yard varies with management direction, influenced by any company standards which may be imposed. Company policies or procedures, however, seldom address standards for planning or scheduling.

Planning managers have relied heavily on their knowledge of past ships and the experience of their individual planners. Most members of the planning staff came from the ranks of the Production department, and therefore, understood the basic essentials of at least their portion of the shipbuilding process.

Planning has normally been decentralized, placing detailed shop planners within the shop environment, and a top level planning group tasked with total ship's schedules and overall yard control. Each reports to different points within upper management which leads to varying levels of management direction, required reporting, and responsibilities.

Some yards attempt to consolidate by centralizing their planning groups. Communications within planning generally improve while links to the Production department tend to blur and disappear with time. The end result being schedules which Production will ignore unless management intervenes heavily.

Regardless of approach, planning was ultimately done "by hand", with various reports drafted by the planners and typed by clerks or secretaries. Tracking of the plan required heavy manual intervention, and rescheduling, when necessary, was usually inaccurate due to the lack of proper information. When such data was compiled, by the time the new schedule was published, it was outdated.

The field of Data Processing has been developing at a rapid pace since 1948. For many years, the computer served an important role in all aspects of industry, including the shipbuilding environment. Until recently, however, the role of the computer in shipbuilding remained at the basic accounting level. It was used to accommodate payroll, accounting, and occasionally, inventory control. With education in the field of software development on the upswing, traditional D.P. systems are being augmented with more sophisticated programs,

now advancing into the realm of Production Control, Planning, and Scheduling. Shipyard D.2. personnel are becoming acclimated to the very nature of the shipbuilding process and are developing computer systems to enhance the capabilities of the planning departments.

This transition has been slow and painful since the rigid discipline of software development, dictated by the logic of the machine, is in direct contrast to the art of shipyard planning. Shipbuilding did not advance with the advent of the computer, as did aerospace cr electronics, and planning personnel have been reluctant to place strong credence in the programmers and their software.

The recent shipbuilding situation, regarding number of awarded contracts, DOD requirements, and the complexity of the vessels, has forced the planners to incorporate some use of the computer in their work. One significant application being the use of PERT systems to aid in the scheduling function. It appears, however, that planning personnel have taken a misguided step into their use of ccmputer software.

In many ways, the speed of the computer has been harnessed to increase the overall document volume generated by the Planning department, but the sophistication of the scftware is not being utilized.. Instead, the yard's traditional planning techniques are being dropped, with no improved methodologies replacing them.

The overall experience levels of the planners is on the decline, caused in part by Management's desires to upgrade the Planning environment with higher education levels. Knowledge of the shipbuilding process, while still important, is taking a "back seat" in attempts to increase the potential of the Planning department. Planning "to suit Production" is replaced with planning "to suit the computer", with the overall approach tending away from the shipbuilding process. D.P. builds, or buys, sophisticated software, and Planning's attitude has shifted towards that software. Insufficient, or incomplete, plans are fed to large programs with the assumption being that said software will create completed schedules. Schedules that are complete, trackable, and consistent with the Production environment, however, cannot be generated by software alone.

No computer software system has been created which understands all of the intricacies of the shipbuilding process, contrary to the assumptions of some planners. The D.P. discipline still holds to the philosophy that the best systems are those which are as general purpose as possible to ehnance their applicability to a multitude of applications. This is particularly true of systems created by software suppliers who want their programs to sell in as many differing environments as possible. If the D.P. department IS asked to create a "scheduling package", their inclination would be to build a system capable of supporting Engineering, ship repair, as well as new construction scheduling. Planning, however, is

seldom aware of this "generality by design", and usually misuses the software.

Planning is not wholly to blame. Management is ultimately responsible for the schedules in terms of short and long range commitments of the yard. However, management appears to be too short-sighted at the onset of the planning process, by not insisting that planning be directed at the overall development of the yard, as well as the individual ships. Management does not fully- understand what is happening in their Planning departments until it is too late, and a ship is behind schedule with no known manner of recovering. It is impossible to recover to a schedule that is incorrect in the first place.

The end result is a Planning department which does not support the needs of the yard. Many of the planning and scheduling details, such as material procurement and testing schedules, are overlooked in favor of feeding steel sequence and major outfitting plans to some piece of computer software. More noticeably, required support schedules for shop work is often ignored, due in part to the fact that such detailed information would yield an overly complex set of data to be input, and eventually extracted, from the computer. To understand this statement, consider a ship requiring 2000 major erection activities. Printed at 50 lines per page would require 40 pages of printout that must be fully understood by Planning. To properly complete the picture, as it should be done, add in 200 Engineering drawing related activities, 500 material tracking activities, 200 major test items, and 4000 shop support

activities. The total number of activities has grown to 6900 to be presented on 138 pages of computer paper. That is, 138 pages of scheduling results which must be as accurate as possible for the yard to effectively function on this construction project.

Output volume is not the only problem concerning the analysis of the plans and schedules. All too often, software packages are deemed best if they present every detail of the data. While detail is necessary, data summarization is required to assist both Planning and Management with a comprehensive overview of the yard's load and problem areas. Few packages, however, are capable of reporting high level summaries, suitable for inspection by middle or top management. In addition, the bulk of the plan's details must be analyzed on an exception basis to allow Planning the ability of focusing on the problems rather than having them piece through all detailed reports for problem. isolation. Of importance to note in this discussion is that general purpose computer programs cannot sufficiently accommodate the specific needs of the American shipyards, both in terms of data summarization and problem isolation by exception reporting.

The Planning environment, whether it be a centralized planning department or decentralized planning groups, has been doing this work for years without a computer to foul things up. But the new Planning/D.P. relationship seems to have short-circuited this total planning process. With the increased speed and storage capabilities of most large scale

computers, planning and scheduling can be done at the yard level as well as the individual ship's level. Total integration of ship, shop, engineering, and material requirements can be accommodated, even considering the increased complexity of the resultant schedules.

A new discipline needs to be developed with regard to planning and its use of the computer. Planners must be trained in the use of the computer software tools which D.P. is presenting to them. Interdepartmental communications need to be restructured in such a fashion as to augment the use of the machine and its output. No longer is the massive amount of data to be a hinderance to the Planner or Management, but rather, an incentive to utilize as much of the computer's power to the benefit of the yard. Support schedules need no longer be isolated from the primary ship's erection schedule just because the total plan seems too large.

Data Processing must also be included in this revitalized Planning approach. Computer software tools must be designed to be industry specific, geared to accommodate the massive data manipulation problems associated with our heavy manufacturing environment. Data must be accessible by many in the yard, yet controllable by minimizing the number of persons capable of updating that information, for the purpose of data integrity. As systems are developed, Data Processing must assist Planning in the establishment of a data control, since numerous factions within the yard will be required to provide input and updates to the data upon which Planning must make meaningful planning

and scheduling decisions. Where multiple programs are involved, Planning and D.P: must work together to insure that all departments in the yard understand their responsibility to the planning endeavor, and that the systems used by those departments maintain information in alignment with some master planning system, whether computerized or manual.

The end result is plausible and possible. Total ship's plans and schedules directly under control by the Planner, all incorporated under the exacting guidelines of the machine. Complex? Surely, but the sophistication of the D.P. department can be used to prepare mechanisms by which the total ship's complexity- can be broken down into finer lines of detail, and be digestible by the differing Planning functions. management also benefits by the increased solidarity of the Planning environment in developing the plans and schedules for individual ships, as well as the entire yard.

The basic premise for re-establishing the proper perspective of the Planning environment is a thorough analysis of the elementary principles upon which shipyard planning is based. The intent of the computer is to serve the needs of the yard, and planning standards and methodologies should not be directed toward the fulfillment of the D.P. department. Instead, an cverall evaluation of the needs of the Planning department must be performed, with the following points being considered:

* Discrete ship, shop, and support planning philosophies
* Techniques and Methodologies

* Required policies and procedures
* A formalized training program

Once the planning discipline is established, computer tools can be properly defined, and the D.P. department can begin its role with regard to the yard's planning needs. With this basic foundation, Planning can then begin to function in its proper capacity, relating the shipyard's short and long term goals in terms of the total environment: Engineering, Material acquisition and control, Production manpower, Facilities, and Data Processing.

The intent of this thesis has been to expound upon some of the pithfall'sfalls of the Planning and Data Processing interaction, as has evolved with the increased capabilities of the computer and its software. It has been observed that, with increased attention to the machine, Planning has lost some of its emphasis on its techniques and methodologies, both at the individual ship level as well as the total yard level. As computers become larger and more powerful, and as the D.P. personnel become more knowledgeable of the shipyard, the emphasis of Planning should be to capitalize on this technology, rather than be directed by it. Increased use of the computer will not solve the Planning dilemma being faced by today's computerized yards, but rather, the Planning department must re-evaluate its position, capabilities, and intentions within the structure of the yard and the industry.

THE OUTFIT PLANNING PROGRAM*

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ABSTRACT

Shipbuilding as currently practiced in the U.S. commerical shipyards employs very little quantitative modeling or analysis in production planning. This paper presents a brief discussion of the shipubilding process and focuses on one major component which is referred to as outfitting. The outfit planning problem is described in detail and then formally modeled as a generalization of the resource constrained project scheduling problem. The value of the approach as well as barriers to its adoption are also discussed.

*This research is supported by the University Research Program of the U.S. Maritime Administration under Contracts DO-AOl-78-00-3074 and MA79SAC00067.

THE OUTFIT PLANNING PROBLEM

1. Introduction

Current practice in planning and scheduling ship production inherently limits the ability to integrate steel and outfit activities. It results in the bulk of outfitting work being performed in the erected hull, either on the ways, after a block is closed in, or at the wet dock or outfit pier. Working conditions in the hull are not ideal because of factors such as difficult access, limited space in which to work, difficulties in adequately venting noxious fumes, and difficult work positions (e.g., overhead welding). The workplace is typically congested, with high material flow costs, and often hazardous conditions.

It is now widely recognized that many of these problems can be relieved to some degree by doing more outfitting activities earlier in the production process, i.e., either in the assembly area or in the shop (vendor) area. To do this, however, requires a much greater integration of steel and outfit planning than has been the rule.

The fundamental problem is to identify economically desirable opportunities for preoutfitting. This requires answering two types of questions. The first is related to feasibility, i.e., "Is there sufficient time and resource available to do a particular outfitting activity in the assembly or shop area, and is it technically feasible?" The second question is one of economics, "Is it more economical to preoutfit the activity?" The answer to this question should take into account any limitations on outfitting resources. What is needed is a systematic way to answer these two questions.

2. PWBS and ZOFM

The Product-Oriented Work Breakdown Structure (PWBS) and the Zone Outfitting Method (ZOFM) are strategic approaches to ship production which have been proven effective through implementation in some of the world's most competetive shipyards. They are key elements in the drive toward better productivity, and there is little doubt that both will become widely-adopted (and hopefully adapted) by U.S. shipbuilders.

PWBS

The traditional definition of outfitting work packages (see, e.g., references 1 or 3) follows naturally from the systems-oriented design of the ship. This work breakdown is appropriate for design and estimating, and simplifies the collection of production data by system. Unfortunately, it also results in work packages which are too large and have too great a duration for truly effective control.

What is needed is a transition from the systems orientation necessary in design to a product orientation which is needed in production. Interestingly, this transition takes place almost instinctively in hull design and construction. PWBS provides a mechanism for also making this transition in outfitting.

PWBS divides the shipbuilding process into three basic types of work, hull construction, outfitting, and painting, and further classifies each type of work as fabrication or assembly. Interim products are classified by resource requirements and certain product features such as type of system (e.g., lighting system) and zone (any geographical division of the ship). It is noted that PWBS bears a close resemblence to group technology. It is quite flexible, and allows activities to be summarized in many different ways.

ZOFM

Zone outfitting is to outfit activities what hull block construction is to steel activities, i.e., it is a logical method for organizing the work to improve planning and productivity. Zone outfitting incorporates three stages for outfitting: on-unit, on-block, and on-board.

Outfitting on-unit refers to the assembly of an interim product consisting of only outfit materials. Examples are water distilling unit, fuel oil purifier unit, pipe passage unit, etc. Outfitting on-unit impacts the shop-related resources and the material handling facilities. It may require additional labor and materials for structural support to units to permit their movement to the assembly or ways areas. It also has some impact on hull construction progress since the unit must be landed. However, "on-unit outfitting should be given the highest priority . . . because assembly is performed in shops which provide ideal climate, lighting, and access" (see reference 2).

Outfitting on-block refers to the installation of outfit components, or units, in a hull block in the assembly area prior to its erection on the ways. Outfitting on-block is more difficult than outfitting on-unit because it requires careful coordination between the steel activities and the outfit activities and may impact the duration of a block's occupation of an assembly area.

Outfitting on-board includes any required outfitting activity which has not been performed in either of the two previous stages. Although outfitting on-board describes outfitting as usually practiced, it also allows for nontraditional activities such as the connection of outfit units or outfitted blocks.

3. The Outfit Planning Problem

Because zone outfitting defines various stages for outfitting, it admits alternatives for the execution of outfit activities. Thus, the full exploitation of the zone outfitting concept requires that production management be able to resolve all the alternative choices available. The problem of resolving the alternatives and defining a single outfit plan is referred to here as the outfit planning problem. In order to explore the problem in more detail, it is helpful to classify outfit elements according to the outfitting options which may be applied.

There are some outfit components which are only installed in the on-board stage, e.g., furnishings and other similar materials which are subject to damage or pilferage are always installed in the on-board mode. These will be designated <u>on-board components</u>. Of the remaining components, some are associated with distributed systems, e.g., wireways or ventilation ducting, rather than with distinct units, e.g., pumps, motors, valves, etc. These will be referred to as <u>non-unit components</u>, since outfitting on-unit is not appropriate. Finally, there are the outfit components which could be identified by or associated with a specific unit. These will be referred to as <u>free components</u>, since they may be installed in any of the three modes. (Note that it is usually desirable to outfit on-unit whenever possible, but it is conceivable that resource limitations might dictate otherwise.)

The designations on-board, non-unit, and free are fixed to some extent by design practices. For example, a given group of outfit components, say a pump and piping, may be conceived and designed in several ways. If it is treated simply as a collection of separate components which must be installed in the ship, then the components will have the non-unit designation.

Alternatively, if the components are viewed as integral parts of a single unit or set of units, then they will have the free designation. Chirillo and Jonson (reference 2) give examples of outfit components that could be associated with units, although they typically are not in U.S. shipyards. Figure 1 illustrates the relationships between the designations and the associated production facilities.

Outfit planning requires, for each outfit component, a selection of outfit mode. The selection decisions are constrained by a number of factors. In particular, it is common practice to take the hull block erection schedule as fixed when planning the outfit activities. For example, each hull block has a fixed deadline for its completion, and at that point in time it is lifted onto the ways for erection. Thus, all on-block outfitting planned for that hull block must be completed before its erection date. Similarly, if a unit is to be installed in the block, all the associated on-unit outfitting must be completed in time to allow the unit to be moved onto the block and installed before the block erection date. Furthermore, if the block closes in any previously erected blocks, any large components (main engine, diesel generators, etc.) must be landed in these blocks prior to Closing in.

The hull block erection schedule is a constraint in outfit planning because of convention. It is also possible to treat the hull block erection schedule as part of the decision process, i.e., if it were justifiable, a hull block might remain in the assembly area longer to allow more on-block outfitting to be performed.

Another constraint which may affect outfit planning decisions in many yards is the available lifting capacity. Outfit units and outfitted hull

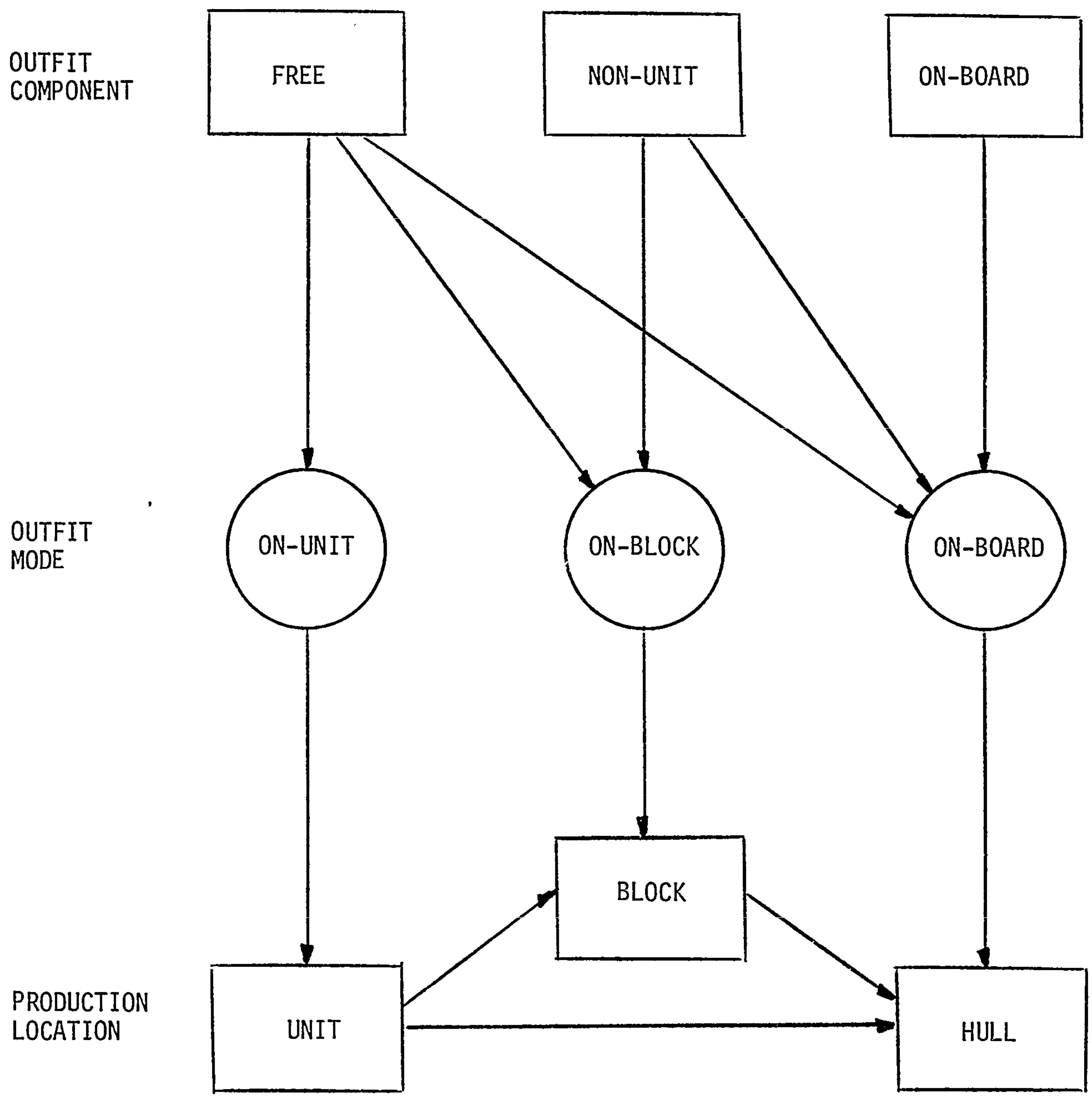

FIGURE 1 Relationships Between Outfit Components, Outfit Mode and Production Location

blocks must not exceed the safe lifting capacity of the available equipment. Size is a similar consideration, i.e., units must be sized in light of the available access.

The effect of outfit planning decisions on limited yard resources must also be considered. Among the resources which are affected are labor and material availability and production or storage space. When determining outfit mode, care is required to insure that the resulting production schedule does not call for more labor than is available in each affected craft and grade. Likewise, since production typically requires space and fabricated components or units may need to be stored temporarily, the available yard facilities must not be overcommitted.

These resource allocation considerations are perhaps the most difficult aspect of outfit planning, especially in situations where multiple ships are in production simultaneously. The reason is that in order to guarantee feasibility of the mode selecions, a feasible schedule must be determined. The selection decisions and subsequent scheduling decisions interact in a complex fashion and cannot be made independently.

Considerable cost savings are indicated (see, e.g., references 2 and 3) for outfitting on-unit and on-block instead of on-board. These cost savings result from lower skill requirements, better material access, less congestion, better quality control, etc. Another result of increased on-unit and on-block outfitting would be reduced delivery time. Reducing delivery time is favorable to both owner and builder, since the owner has use of his ship sooner and the builder receives final payment sooner. In addition, the owner benefits from the reduced ". . . interest costs for the substantial accumulating investment represented by construction progress and for achiev-

ing maximum utilization of expensive facilities such as a building dock" (reference 2).

Thus, two goals to strive for in making the outfit planning decisions are to minimize outfitting costs and to minimize the completion time for the ship. In particular circumstances, other goals might be relevant.

The outfit planning problem can now be stated more precisely as follows:

Given: (1) a catalog of the outfit elements for which there are outfit mode options,

(2) for each such element, a list of the outfitting mode options, including time, resource and precedence requirements,

(3) the key events schedule and possibly the hull block erection schedule,

(4) outfit labor availability by craft and grade,

(5) outfit facility capacities and availabilities,

(6) other constraining factors , such as material availability, rate of cost accumulation, etc.,

Determine: The outfitting mode to be used for each outfit element and the specification of the associated work packages, along with the associated production schedule.

4. A Decision Support System

The traditional approach to outfit planning can easily result in 2500 outfitting work packages, each requiring between 200 and 2000 manhours, and having durations of 3 months or more. The full adoption of PWBS and ZOFM will lead to a larger number of more tightly defined work packages. Current practice typically has one individual responsible for outfit planning. Clearly, one individual using only manual techniques can not adequately consider, for so many elements, the range of outfit mode options that are possible with ZOFM.

A system is needed for helping the outfit planner cope with the multitude of outfit elements, outfit mode options, and resulting outfit work packages. Such a system would need to be computer oriented for most large scale applications, and would need access to a reasonably detailed production data base, such as the SPARDIS system developed by NAASCO (see reference 4).

A well designed decision support system (or DSS) would have several important features. It would be useful not only for initial planning and scheduling, but would also be capable of replanning and rescheduling in response to major unforseen events (strikes, material shortages, rush jobs, facility problems, etc.) or simply accumulated deviations from the original plan. Thus, the system must use both engineering standards and other planning data, and actual production progress or status data.

The DSS should <u>recommend</u> outfit mode selection and work package scheduling decisions, and should allow the outfit planner to averride these recommedations. Note this means that the DSS must incorporate some technique for solving the outfit planning problem as stated in the previous section.

Finally, the DSS should be interactive, so that the outfit planner can use the system without needing either computer expertise or a computer programmer to act as the interface. Figure 2 summarizes these requirements in an overview fashion. The important features shown in the figure are: (1) the human is always the key component in the process, and (2) the process can be iterative. The outfit planner may look at several solutions before he releases one to production. Also, the process can be repeated as many times as necessary.

The commercial development of a DSS for outfit planning requires first of all a large effort in data base design and implementation. The techniques required, however, are all well known. Obviously, the system should incorporate needed elements from PWBS and ZOFM. There remains one element of the system for which there are no readily available techniques. This is the element concerned with solving the outfit planning problem in order to recommend solutions to the outfit planner.

A formal mathematical model of the outfit planning problem has been developed and is described in detail in reference 4. Based on this mathematical model, a solution procedure has been designed and is currently being implemented in experimental software. Also, a testbed problem is being developed, based on actual outfit data from a current ship production project. Results of exercising the solution procedure on the testbed problem will be reported on in the near future. Interested readers may contact the authors for further details.

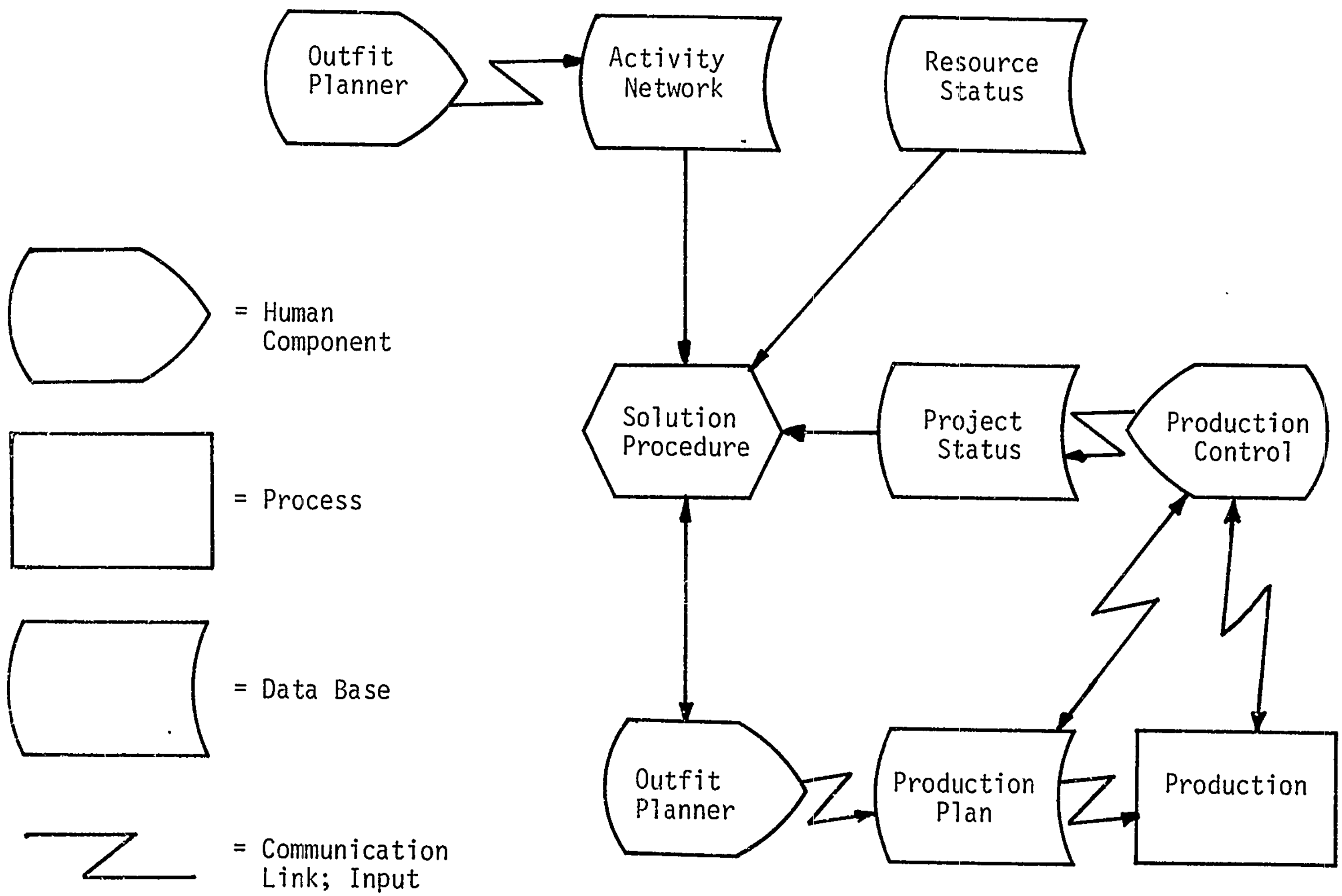

Figure 2 Outfit Planning Process

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DRAWING OFFICE TO PART CUTTING WITH A MINI-BASED ON-LINE SYSTEM

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ABSTRACT

Port Weller Dry Docks, a small, progressive Canadian shipyard has recently installed AUTOKON-79, AUTOPART, AUTONEST and developed several pipe fabrication and installation programs on an in-house PRIME 550 minicomputer. In addition, the company has purchased several graphic peripherals and a Union Carbide Plasma burning machine with DNC capabilities that are used in conjunction with the software.

This paper summarizes the reasons for making these moves, the justifications, and the problems encountered.

1 Overview of the Computer-related Changes Made at P.W.D.D.

In the last year, many computer-related changes have occured at Port Weller Dry Docks. These changes include the purchase of the following hardware components:

- a PRIME P 550 computer and related hardware
- two additional TEKTRONIX 4014 graphic terminals
- a TEKTRONIX 4863 plotter
- a CALCOMP 960 plotter with a 907 controller
- a UNION CARBIDE CM-150 plasma burning machine

In addition, PORT WELLER purchased the AUTOKON-79 application software package from SHIPPING RESEARCH SERVICES.

2 Hardware Description

2.1 The PRIME Computer.

The computer purchased consists of the central processing unit, three-quarters of a megabyte of error detecting and correcting main memory, one AMLC (asynchronous multi-line controller) board that allows lb peripheral devices to communicate with the computer, a 75 IPS, 1600 BPI magnetic tape driver, and two disk drives for the storage of databases and programs. Each disk drive has the capacity of storing approximately 80 million bytes of information.

In addition, several other minor peripherals were either purchased or 'borrowed' from the previously used SPERRY-UNIVAC mini-computer. These include several VOLKER-CRAIG CRT'S two PRINTRONIX 300 line per minute printers;, and a FACIT serially interfaced paper tape punch.

2.2 The TEKTRONIX equipment

Prior to the purchase of the equipment described in this paper PWDD had purchased a TEKTRONIX 4014 graphic crt with the enhanced graphics option, and a TEKTRONIX 4662 plotter. Both of these devices were used on our 'other' computer for the validation of ESSI elements. The 4662 is a very small, slow flatbed plotter with a plotting area of 11. by 15 inches.

The additional TEKTRONIX equipment purchased consisted of two 4014's identical to the existing one and a TEKTRONIX 4663 flat bed plotter. The 4663 is larger (15 by 22 inches), faster than the 4662 and has many additional features (some that are extra cost options) that are heavily used. For example, all circular elements are generated by the 4663 with a single 'draw an arc' command from a computer program in the PRIME. The 4662 requires the driving program to fabricate a circular element a5 a large number of very short chords. This feature'greatly reduces CPU and data transmission overhead, and a5 a result, increase5 plotting throughput.

Secondly, the 4663 can accommodate two pens of a different colour. This feature allows us to use one colour to show 'burning' while the other colour represents 'rapid traverse' while drawing ESSI elements. Again this represent5 an increase in throughput because the many pen UP pen down pen accelerate and pen decelerate operations found in the conventional dashed line representation of rapid traverse lines are not required.

A third heavily used 'additional' feature of the 4663, is its capability to feed paper over the plotting surface from a roll of paper stored on the plotter. This allows continuous plotting of ESSI element5 without any operator intervention. The program in the PRIME produces one plot, moves the paper, produces the next plot...........

2.3 The CALCOMP plotter

The CALCOMP 960 plotter is a mylar 'loop' plotter that is a cross between a flatbed and drum plotter. A5 such, it has both the good and bad features of each concept of plotter. The plotting surface is large enough to handle nearly all of PWDD's plotting requirement5 (33 by 60 inches). Two pens are available, giving it the speed advantage found in the TEKTRONIX 4663 plotter. Plotting speed is very fast --- 30 inches per second axial, 42 inches per second diagonal. Pen acceleration is 4g axially. Plotting resolution is 0.0005 in.

The 907 controller interface5 the 960 plotter to the PRIME computer. It is a micro-processor based device that has many additional features not found in the 960 plotter. In addition to containing a 2K byte buffer, circular elements and dashed line5 can be generated with very short commands from a program in the PRIME, thus reducing CPU and data transmission overhead.

2.4 The UNION CARBIDE CM-150 plasma burning machine

The UNION CARBIDE CM-150 gantry style burning machine is equipped with two plasma arc torches, two zinc powder spray marking unit5 and is controlled by a COMPUTER AUTOMATION mini-computer. The torches are powered by two 600 amp power supplies.

By using a newly developed height sensor, underwater cutting was achieved, thus eliminating noise, smoke and ultra-violet rays. This is done in one of the three pair5 of 13 by 38 foot water tables. Water from a reservoir beneath the tables is forced over the plates to be cut using compressed air. The flooding process. takes only a few seconds.

Cutting is performed at a rate of 90 inches per minute through 12 MM plate. Zinc marking is performed at 90 inches per minute, with intermediate rapid traverse at 250 inches per minute.

The COMPUTER AUTOMATION mini-computer is equipped with a keyboard, paper tape reader, five inch CRT and floppy disk. Burning instructions can be manually entered into the computers memory via the keyboard, or to the floppy disk via the paper tape reader or over telephone lines directly from the PRIME computer.

3 Reasons for upgrading PWDD's computer facilities

Prior to adding the additional computer power, PORT WELLER DRY DOCKS used the services of a service bureau's UNIVAC 1108 computer. The 1108 was a fairly old machine, and its reliability posed a problem to PWDD's production schedule. The machine was 'down' on a near regular basis. Turnaround time was not as good as should be expected because, in addition to its already heavy workload all users were behind following an extended period of down time.

However, the service bureau replaced the 1108 with a faster, much more expensive UNIVAC 1180/1 computer. As the turnaround speed increased, so did the cost of the services !

In addition, SHIPPING RESEARCH SERVICES were beginning to market some interactive ship building packages. Because of their interactive nature and the distances involved, the cost of data communications would have prohibited their use.

By this point in time, technology in the mini-computer field had advanced to the stage where several mini-computer vendors were offering reasonably priced machines capable of handling the AUTOKON package.

The combination of the above warranted a serious investigation of the feasability of 'in-house' AUTOKON. After careful study the decision was made to purchase the PRIME computer, TEKTRONIX graphic peripherals and the AUTOKON-79 software. The decision to purchase the CALCOMP plotter came a5 a result of continuous unreliability of PWDD’s existing large flatbed plotter.

4 Reasons for upqradinq PWDD's flame cutting facilities

The plasma machine was purchased to realize increased speed and accuracy over the oxy-fuel machine that it replaced. Cutting costs and fit-up costs have been greatly reduced. Gutting speed5 were increased by about 400 % and accuracy is now +/- 1 MM as compared to +/- 3 MM for the oxy-fuel cutting.

5 Additional Software

5.1 The Pipe System

Several year5 ago, PWDD purchased CONRAC pipe bending and WELCA cutting machines. The machines are not numerically controlled, but rather are manually controlled from a panel containing several function switches and dials. The bending machines are capable of bending up to 8 inch pipe cold and the cutting machine can cut mitre, saddle, contour and bevelled end5 and holes.

When the machine5 were first used, the pipe squad had to perform a large series of tricky trigonometric calculations to determine the machine setup. Not only were these calculations time consuming and a Source of much frustration, they were prone to many errors.

Several computer programs were written to reduce same of the drawback5 associated with the use of these pipe preparation machines. The pipe squad fed the ship coordinates of each critical point in a pipe to the computer. The computer then performed all of the calculation5 and printed a report that is used by the machine operator to setup hi5 machine.

This approach was a vast improvement, but still allowed errors to s1ip through. Graphical feedback was needed. The appropriate program5 were written to draw a single line representation of the pipes that were fed into the computer by the pipe squad. This reduced errors before they got to the pipe shop and therefore reduced

wasted materials and manhours.

Recently, the decision to expand the computer's role in the piping operation ha5 been made. The expanded concept includes :

-extending the graphic capabilities to allow the computer to draw 'pipe details' (rather than doing it manually) to draw 'installation drawings' that can be given to a pipe-fitter when he goes aboard ship and to draw composite drawings' of entire piping systems.

-establishing a pipe database that contains details and statistical data. This will allow the pipe shop to minimize machine setup time because they will be able to extract pipe5 by 'categories' . For example they will be able to ask for a list of 'all seamless 4 inch pipe that are ready to be bent'. In addition J the planning department will be able to track the progress of pipe systems a5 they move through the various Work stations.

-prepare installation packages consisting of 'installation diagrams' and a material requisition list of all materials needed by'the pipe fitter to perform the installation.

At this point in time, only a limited portion of the expanded concept is in active use. The additional required software is currently under development.

5.2 The Hull Steel Software

The AUTOKON software was updated to include all new developments and enhancement5 to the SHIPPING RESEARCH SERVICES software. The most significant additions were TRALOS TRADET, and DRAW programs for the design office, and AUTOPART, AUTONEST, and AUTODRAW for the mould loft.

The design programs are used to load all internal Structure, and has the facility for providing drawings for use by designers. The information can later be retrieved by programmer5 for the production of coded parts for N/C flame cutting.

The production programs are accessed with a graphic terminal and allow5 an N/C part coder to interactively code a part, or nest' previously coded part5 at the terminal. This concept greatly reduces lead time required by the mould loft.

6 Problems Encountered During the Expansion

6.1 Hardware Installation and Reliability.

All hardware was installed in early November, 1979. The PRIME computer, disk and tape drives, and one of the 300 LPM printers were installed in PWDD's existing computer room which is located in our main administrative building. The balance of the hardware was installed in PWDD's *old' computer room that is located in the mould loft, adJaCent to the men who deal with the AUTOKON system an a daily basis.

The decision to install the PRIME computer and major peripherals in PWDD's existing computer room, as opposed to in the loft was based upon two years experience of having a computer located in the loft. The loft location had several deficiencies that were hazardous to the successful operation of a computer. These include electronic pollution in the farm of radar, from ships passing through the WELLAND CANAL; electronic pollution from heavy welding and gouging operations located in the shop below the mould loft.; noise an the electrical power lines caused by heavy power usage in the shop below; vibration problems resulting from the two 10 ton crane5 in the shop; and a general dust problem resulting from dirt particles migrating from the shop into the computer area.

The distance between the two locations, about 400 metres, posed the first installation problem. It was necessary to run a shielded multi-conductor (52 pairs) cable from the computer to it5 peripherals. In addition, the distance required signal amplification in the farm of short range modems at either end of each RS-232 communications line. The other communication5 lines, set up to run 20 ma current looop, did not require these modems.

Installing the PRIME computer along side the original

computer posed the second problem. Because of the electrical demand5 found in a shipyard, the power sources are Subject to Certain noise and instability that are detrimental to the successful operation of a computer. PWDD had resolved the problem by installing several voltage stabilizing transformer5 to protect the original computer. However, there was not enough capacity in these unit5 to accommodate the additional power requirement of the second camputer, nor was there enough physical room to add additional units. A5 a result, it was necessary to install a new 75 KVA voltage stabilizing unit in place of the older, smaller ones. The unit5 that were removed were relocated to protect the graphic peripheral5 in the loft area.

The hardware ha5 been installed and running for nearly a year. It has performed remarkably well with only minor problems. One disk drive went down thanks to a washer that was floating freely in the area of the coil that controls the head movement. This caused major damage to the drive. Prime <u>REPLACED</u> the entire drive. Other minor problems have occured, but nothing significant enough to interrupt the use of the machine for longer than a couple of hours.

Only one major disappointment in the area of expected hardware performance ha5 occured. The TEKTRONIX 4663 plotter was purchased with the understanding that ball paint pen5 could be used to get the very fine plot line required to check accuracy in tenth scale drawings. Unfortunately, TEKTRONIX has not been able to deliver such a pen even after being pressured to fulfill their end of the contract concerning this matter. Currently, felt tip pens must be used, yielding a plot line that is fairly wide.

6.2 Systems Software

Although the software supplied by SRS could directly be run on the PRIME with little or no change, it was necessary to write additional programs to organize data structures, control resources, drive graphic5 devices, and generally make the best use of the hardware and software in a5 foolproof and simple a fashion a5 possible.

All data file5 are separated into 'project areas-' on the disk. A typical project area is the aft end of a ship. These project areas are further divided into three 'sub-areas': one far ALKON part manuscripts, one for NEST

manuscripts, and one far miscellaneous files. Each of these 'sub-areas' is further divided into three sections: one far input text files (manuscripts), one for output print files, and one far paper tape image files. Corresponding file5 in each of these final three areas have the same name.

With this 'tree structure' approach, file5 seldom get lost and can be collectively manipulated, thus reducing housekeeping to a minimum.

The non-interactive software supplied by SRS runs in a fashion similar to the way it runs on a large mainframe Computer. A JCL file and data file are presented to the computer, which in turn executes the specified program producing a listing and perhaps a paper tape file. A5 in the mainframe, one and only one program may manipulate a database at any given time. To ensure this is the case, and to eliminate the concept of JCL file5 entirely, PWDD developed a queuing system.

An operator will 'Iogin' to a specific area of a project, type a manuscript into a file, and then instruct the computer to execute a program with a simple command such as 'Q ALKON PART 12' *to* run ALKON using manuscript PART 12. The queuing system takes over. It maintains a queue for each database, each plotter and the paper tape punch. *If one* of these resources ha5 a 'Job' waiting to run, if no other 'Jab' is using the resource, and if the computer is not already working to hard (page fault count is respectable>, the queue dispatcher will initiate the Job. This is done by taking a 'JCL template' file filling in the appropriate blanks (project number, database name, data file name.....) to generate an appropriate JCL file, and finally starting the JCL stream into execution. When the Job finishes, it automatically notifies the dispatcher program that this is the case. The dispatcher will start the *next* Job far that device or database.

A queue monitor was also written. This allows any operator or data entry clerk to manually control the queuing system. for example, the operator can stop the dispatcher from starting any new Jobs for a given queue, manipulate the order of queue entries, delete entries from a given queue, or re-route platter requests from one plotter to another.

In addition' this monitor displays certain performance characteristics for each 'Job' and or user in the system. Such detail5 a5 accumulated CPU and I/0 time, amount of memory occupied....are available at a glance. Also, general machine performance characteristics are displayed. These include page fault information, CPU usage and I/0 activity.

An additional data manipulation system has recently been installed. This concern5 the control of data transfers from the PRIME computer to the UNION CARBIDE plasma flame cutting machine. Once an ESSI tape ha5 been validated and approved by the mould loft' an entry is made into the control file indicating that this is the case. The shop can interactively inspect this control file to determine which of the 'released' burn tape5 they wish to select far their burning schedules. Once the selection is made, an operator in the shop will instruct the PRIME to transfer the burn tape electronically over telephone lines to a file on the plasma cutting machines floppy disk. A5 the transfer of files takes place, the PRIME computer records when' and where the file has been transfered.

This DNC approach virtually eliminates paper tape at PWDD and automatically prepare5 records of burn tape transfer5 from the mould loft to the shop.

6.3 SRS Software

The installation of the SRS software on the PRIME computer was a massive undertaking. Not only was there several hundred thousand lines of field proven programs to be converted to run on the PRIME, but there were the new programs, which were not fully field proven, to install. Taking this into consideration' it must be stated that the SRS software is, in the mast part, holding its own on our mini.

The initial release of the proven software did contain several 'bugs' that have now been fixed. Periodically' PWDD uncovers new 'bugs' in the newer programs. As they are uncovered' the are fixed--either by PWDD staff' or, if the bugs are of a major nature, by SRS staff. Soon, this software will be fully field proven.

The mast significant disappointment in the software enhancements' from a 'systems man' point of view' is the database incompatibility between the various systems.

ALKON,TRALOS,TRADET and DRAW employ the AUTOBASE type database. AUTOPART and AUTONEST each employ their awn style of database. Although this approach was taken to facilitate the necessary quick response time needed in an interactive system, in require5 careful management to control the transfer of appropriate infarmation from one database storage method to another.

7 Summary

PORT WELLER DRY DOCKS is a pioneer in many areas of shipbuilding. One of these areas is in the use of an 'in-house' mini-computer for N/C tape preparation. Being a pioneer can be very expensive---a l&t of hard work, a fairly extensive capital layout, n&n-productive time smoothing out the rough areas, learning from our awn mistakes as opposed to the mistakes of others......

However' the efforts of our pioneering are now beginning to bear fruit and will continue to do so in an ever increasing fashion as time progresses.

STEERBEAR 3 WITH INTERACTIVE GRAPHICS

Kai Holmgren
Managing Director
Kokums Computer Systems AB

Mr. Holmgren's main task is supervision of the integrated computer-based systems STEERBEAR and SYSTEM Q, which are used at Kokums and at a number of other yards throughtout the world. He holds a degree in Economics. Past experience includes the position of system analyst at the Swedish Aircraft Company, and head of engineering computer applications at the Swedish Aero-engine company.

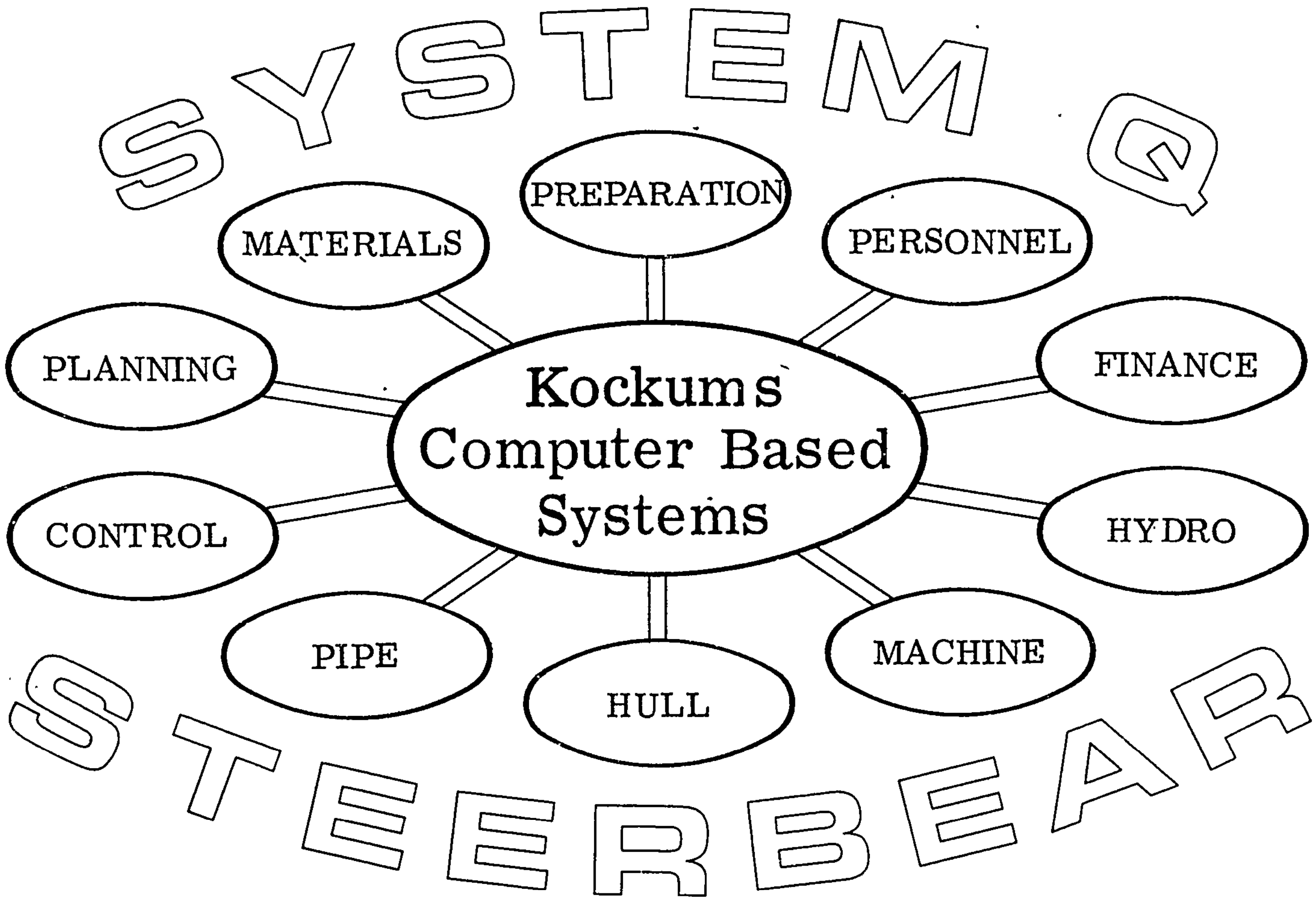
ABSTRACT

The development of the next generation of STEERBEAR (SB 3) is underway. The efforts are concentrated on general basic software adapted to interactive graphics and suited to a variety of applications and in particular to a new STEERBEAR HULL system (SBH 3). The main new features of SBH 3 will be:

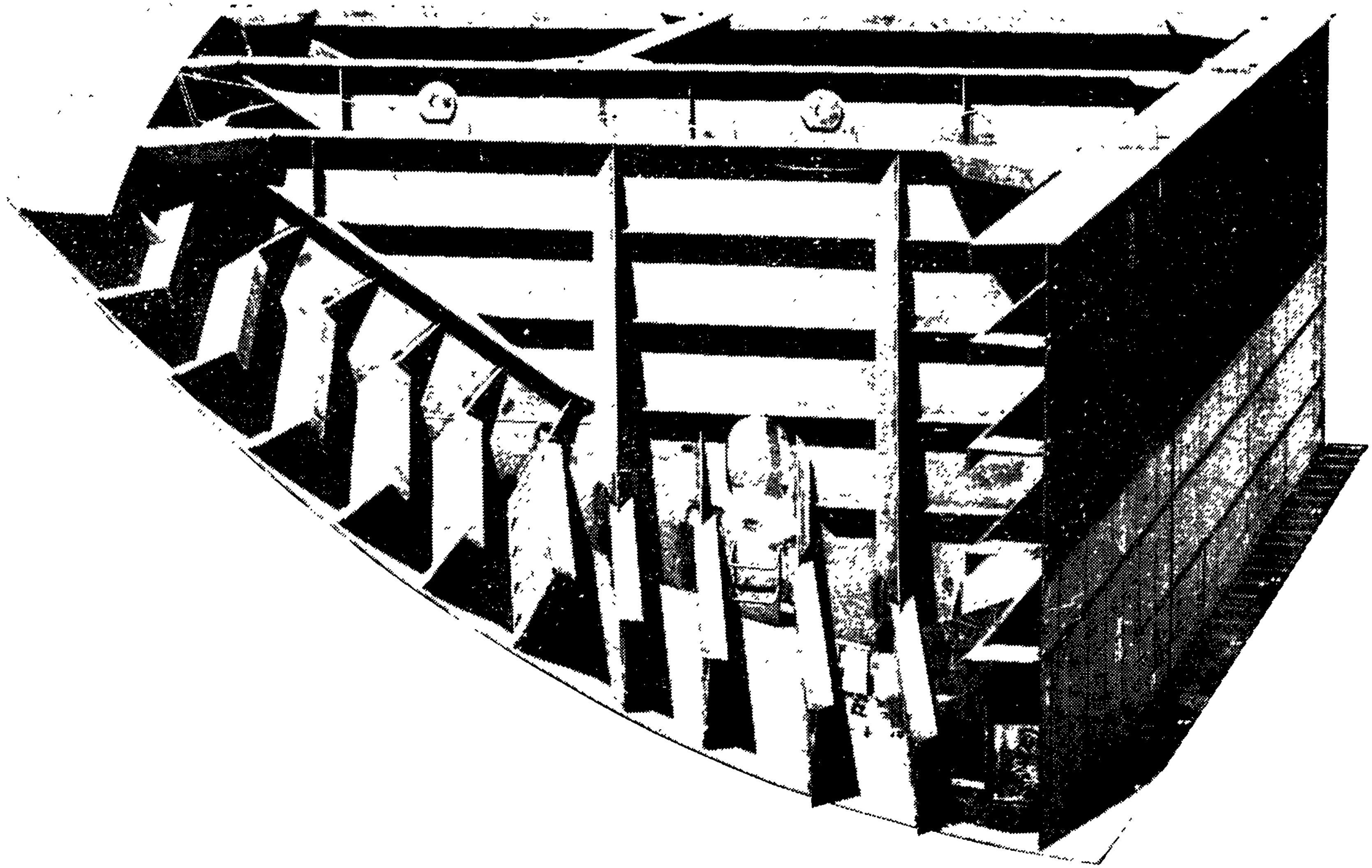
- Interactive graphics available where feasible.
- Improved facilities for generation and handling of three-dimensional curves and surfaces.
- Parametric design modules covering more complex elements than in SBH 2.
- Improved facilities to create and use a 'product description'.
- Distribution of the computer work between main frames, mini- and microcomputers.

A system work station is composed of a Digital Equipment microcomputer, a Tekronix storage tube with refresh capability, an alphanumeric screen and a graphic tablet. Basic graphic software has been developed and is operational on the work station. Within a few months the system work station will be used to present graphic output from SBH 2. The computers used are a PDP 11/34 and an IBM main frame.

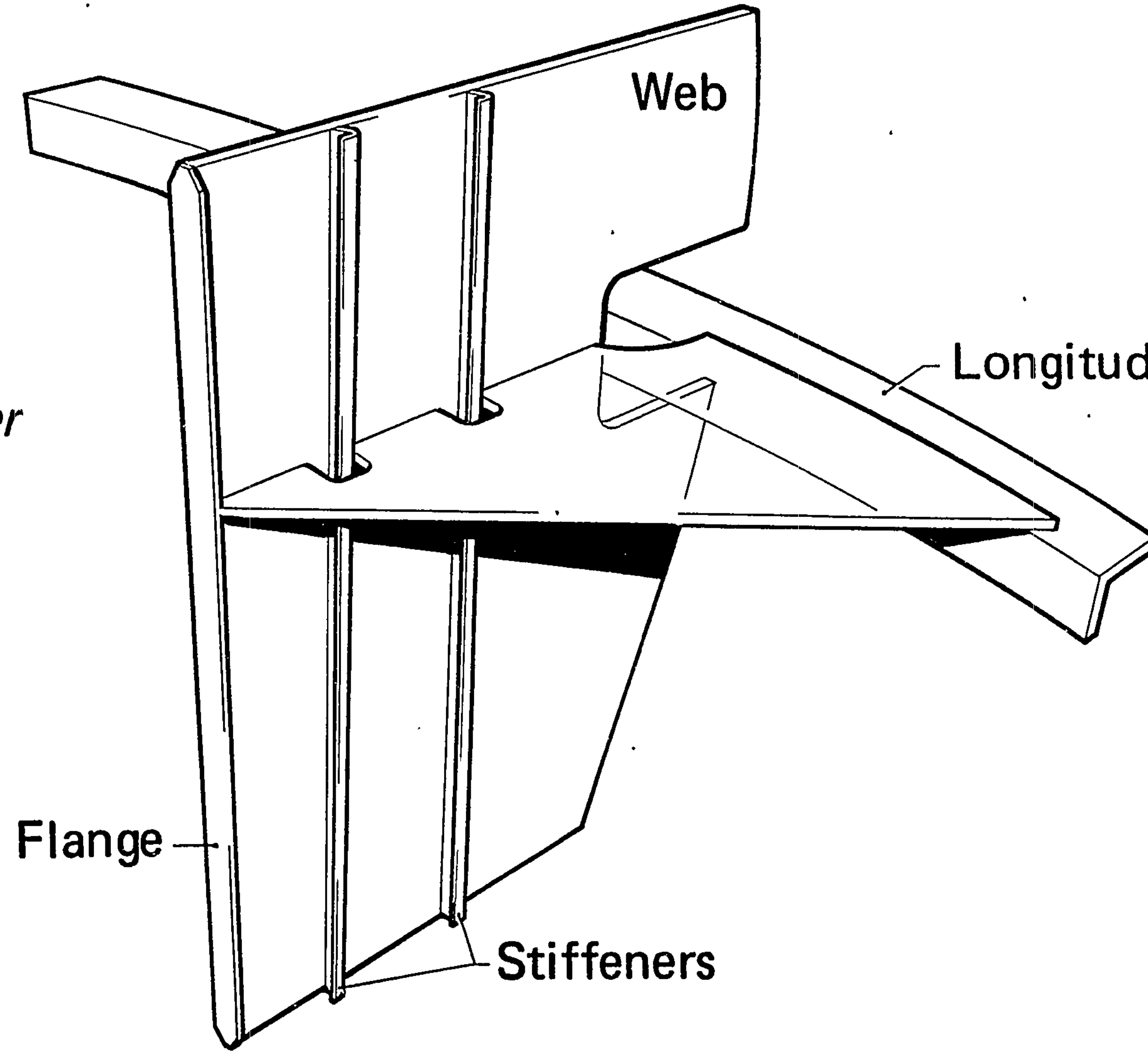
During the first quarter of 1981 a system for interactive working drawing composition will be in operation connected to SBH 2. Text and drawings generated by the current structure generation system can be combined and supplemented at the work station and then be returned to the main frame for further processing. The total development program of SBH 3 including basis interactive fairing and interactive nesting will be finished before the end of 1982.


SYSTEM Q
PREPARATION
MATERIALS
PERSONNEL
PLANNING
FINANCE
Kockums
Computer Based
Systems
CONTROL
HYDRO
PIPE
MACHINE
HULL
STEERBEAR

The panel concept



Tripping bracket

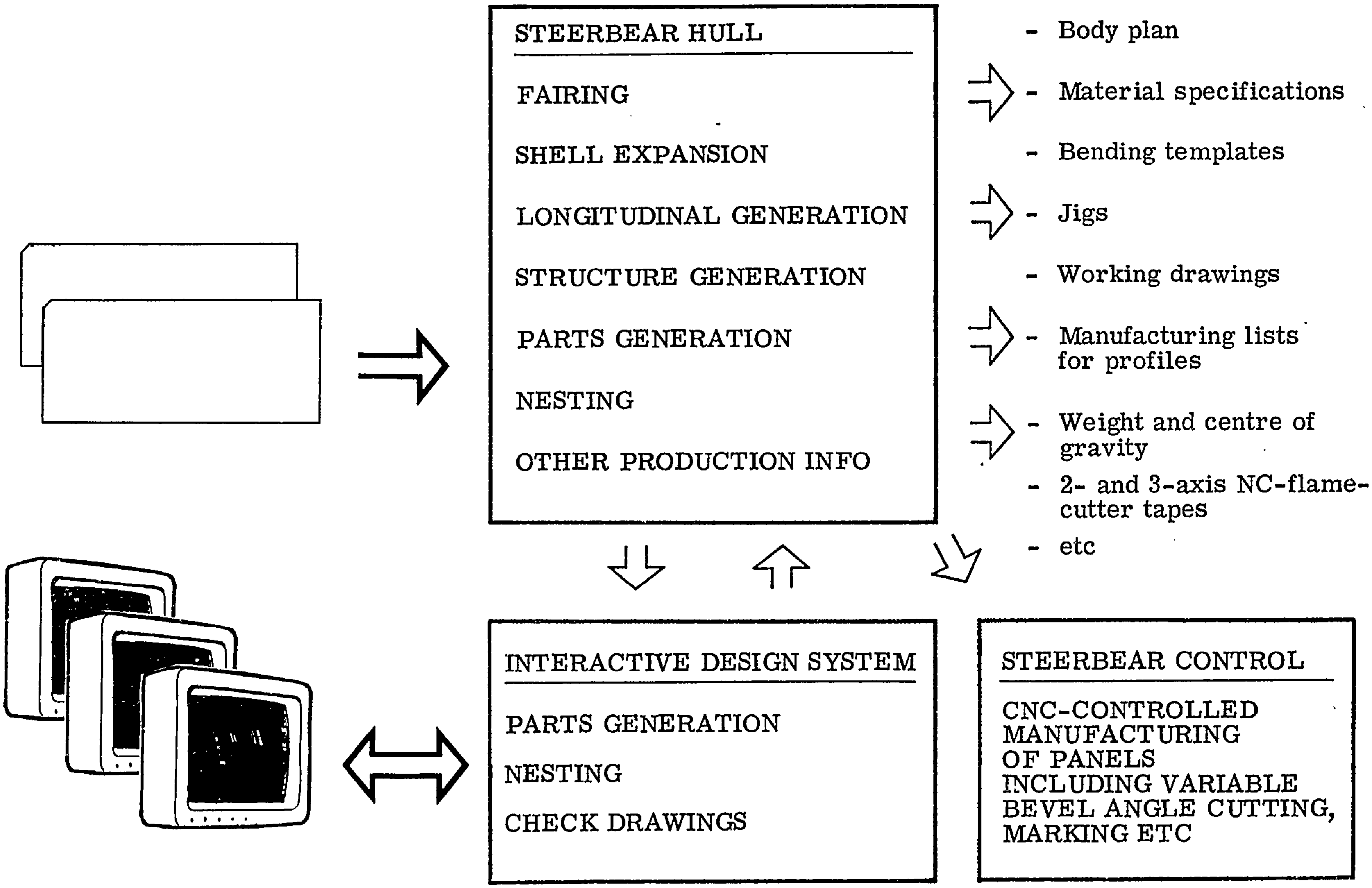


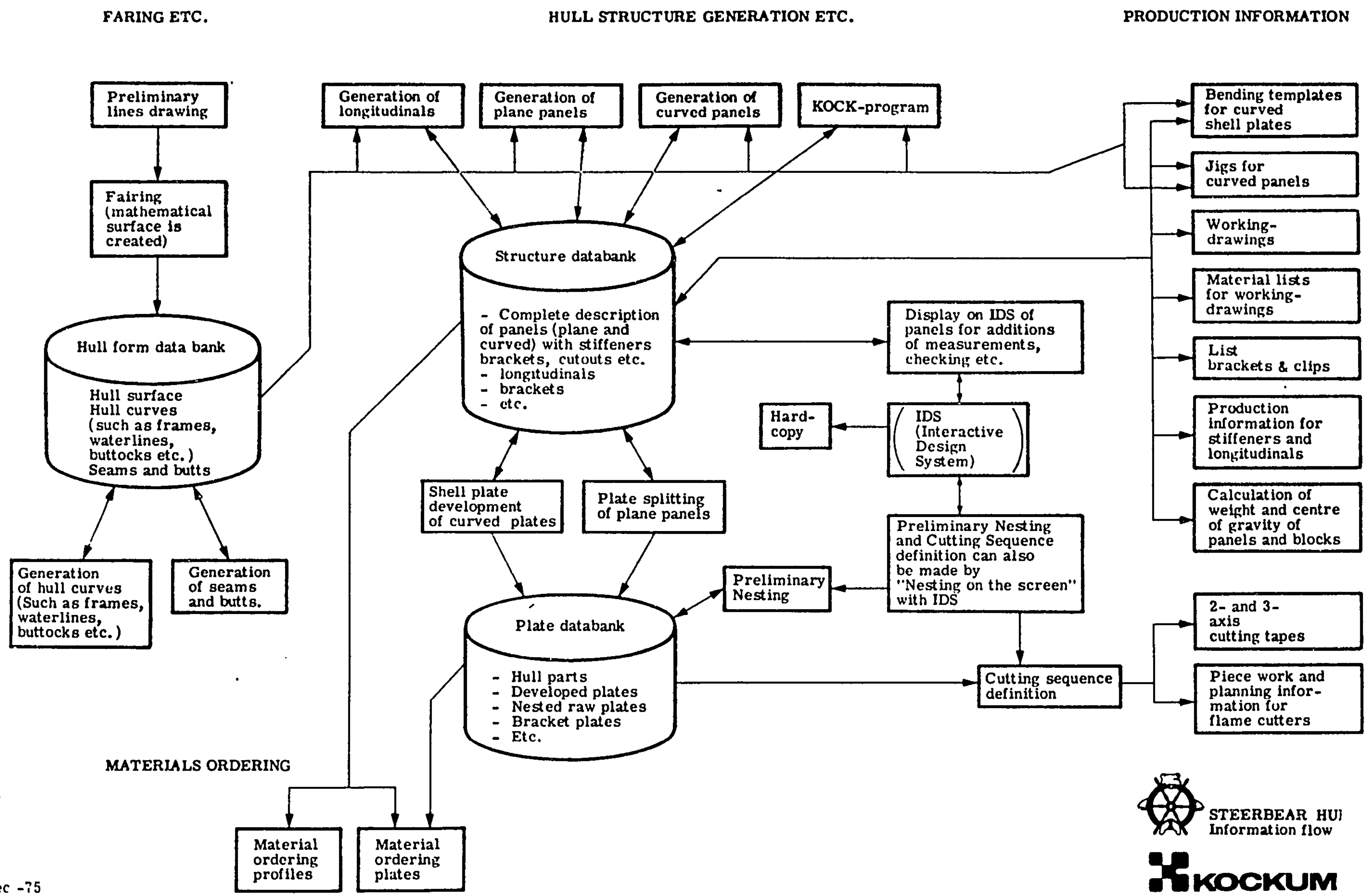
Input:

- *Connection code*
- *Longitudinal number*
- *Thickness*
- *Side*
- *Quality*

Result:

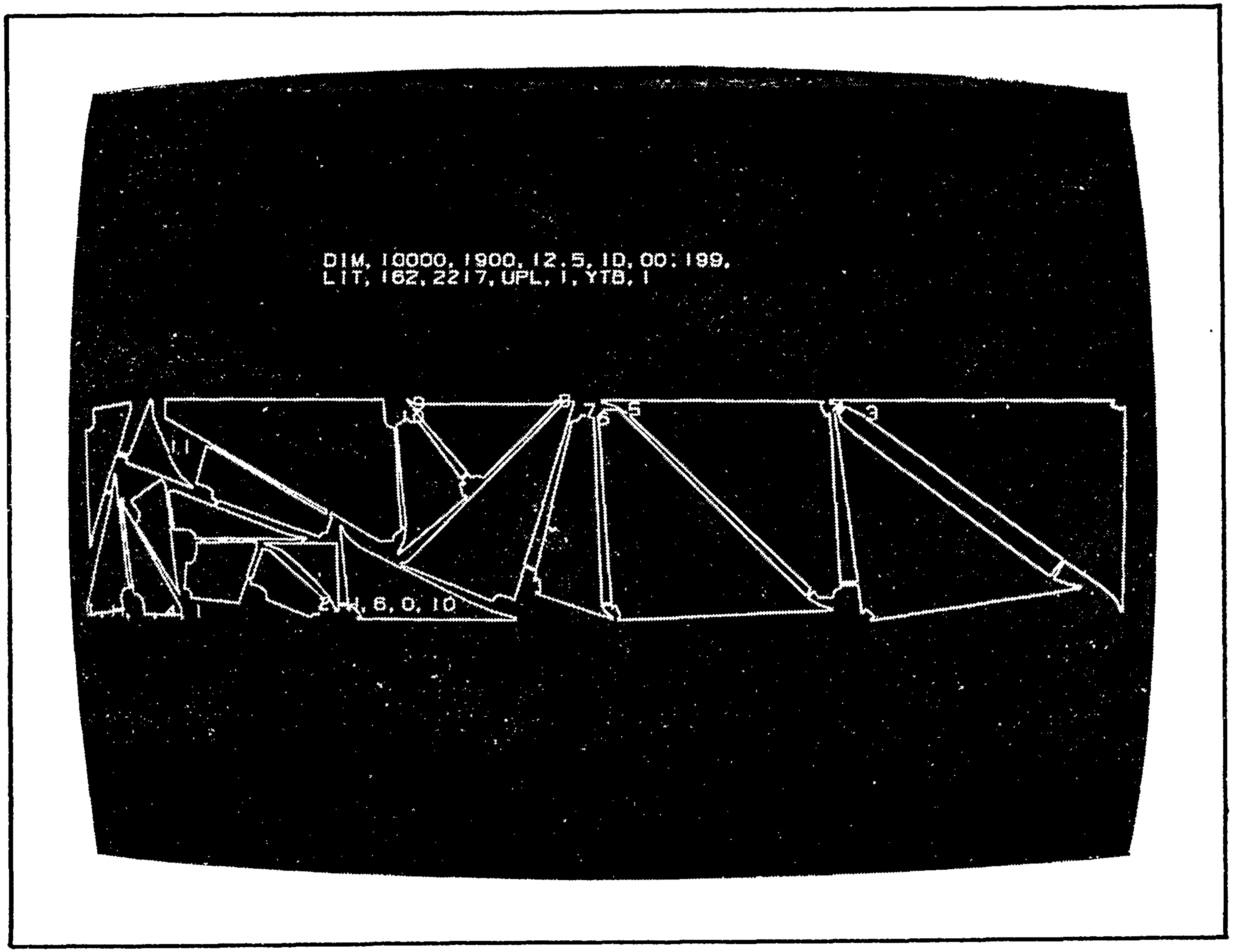
The bracket generated and stored


STEERBEAR HULL
FAIRING
SHELL EXPANSION
LONGITUDINAL GENERATION
STRUCTURE GENERATION
PARTS GENERATION
NESTING
OTHER PRODUCTION INFO
- Body plan
- Material specifications
- Bending templates
- Jigs
- Working drawings
- Manufacturing lists for profiles
- Weight and centre of gravity
- 2- and 3-axis NC-flame-cutter tapes
- etc
INTERACTIVE DESIGN SYSTEM
PARTS GENERATION
NESTING
CHECK DRAWINGS
STEERBEAR CONTROL
CNC-CONTROLLED MANUFACTURING OF PANELS INCLUDING VARIABLE BEVEL ANGLE CUTTING, MARKING ETC

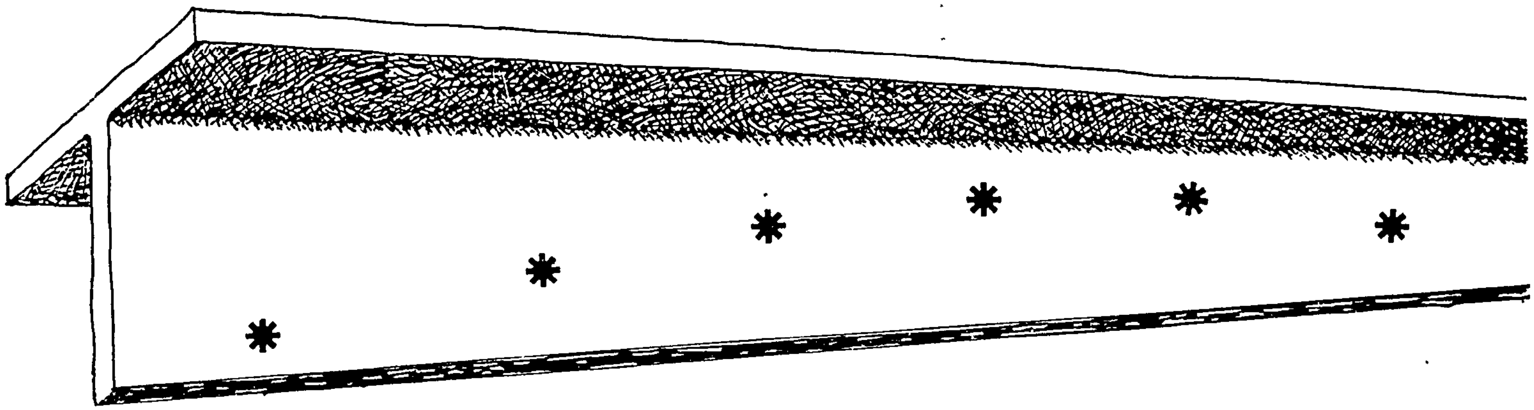

FARING ETC.
HULL STRUCTURE GENERATION ETC.
PRODUCTION INFORMATION
Preliminary lines drawing
Fairing (mathematical surface is created)
Hull form data bank
Hull surface
Hull curves
(such as frames, waterlines, buttocks etc.)
Seams and butts
Generation of hull curves (Such as frames, waterlines, buttocks etc.)
Generation of seams and butts.
Generation of longitudinals
Generation of plane panels
Generation of curved panels
KOCK-program
Structure databank
- Complete description of panels (plane and curved) with stiffeners brackets, cutouts etc.
- longitudinals
- brackets
- etc.
Shell plate development of curved plates
Plate splitting of plane panels
Plate databank
- Hull parts
- Developed plates
- Nested raw plates
- Bracket plates
- Etc.
Display on IDS of panels for additions of measurements, checking etc.
Hard-copy
IDS (Interactive Design System)
Preliminary Nesting and Cutting Sequence definition can also be made by "Nesting on the screen" with IDS
Preliminary Nesting
Cutting sequence definition
Bending templates for curved shell plates
Jigs for curved panels
Working-drawings
Material lists for working-drawings
List brackets & clips
Production information for stiffeners and longitudinals
Calculation of weight and centre of gravity of panels and blocks
2- and 3-axis cutting tapes
Piece work and planning information for flame cutters
MATERIALS ORDERING
Material ordering profiles
Material ordering plates
STEERBEAR HUL
Information flow
KOCKUM

Dec -75

Complete nesting



Longitudinal bending table



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  KOCKUMS MEK. VERKSTADS AB    MANUFACTURING LIST FOR LONGITUDINALS   DRAWINGNR   PRODUCTNR  SPNR .WONR    PLU  PAGE
  TS109A * STEERBEAR 2 BY KMV *                 750507                122/30252/-    510552   122  2331  23371    1

                   / S S  / P S /        /               E  N  D  C  U  T  C  O  D  E
RNR-GNR-PNR LENGTH /DS AS /DS AS/ WEIGHT/    TYPE    MARK      A   B   C  R1  R2    V1  V2  V3    V4    BEVL  BEVF
=====================================================================================================================
222-3-3      14731 /-- -- / 1 --/  1223 /  *1*  21    AFT                 75         90.0  90
- - - - - - - - - - - - - - - - - - - - /  *2*  21                                   90.0  30
TYPE/DIM:31/500*120*13.5*35.0           /
BYINGMARK :451215                       /
                 +++++ H O L E +++++
HE150*75        V=53   U=3108,10394,13392


                                    B E N D I N G   T A B L E

                     =====================================================
                     /            /            /             /           /
                     /DIST HEIGHT /DIST HEIGHT /DIST HEIGHT  /DIST HEIGHT /
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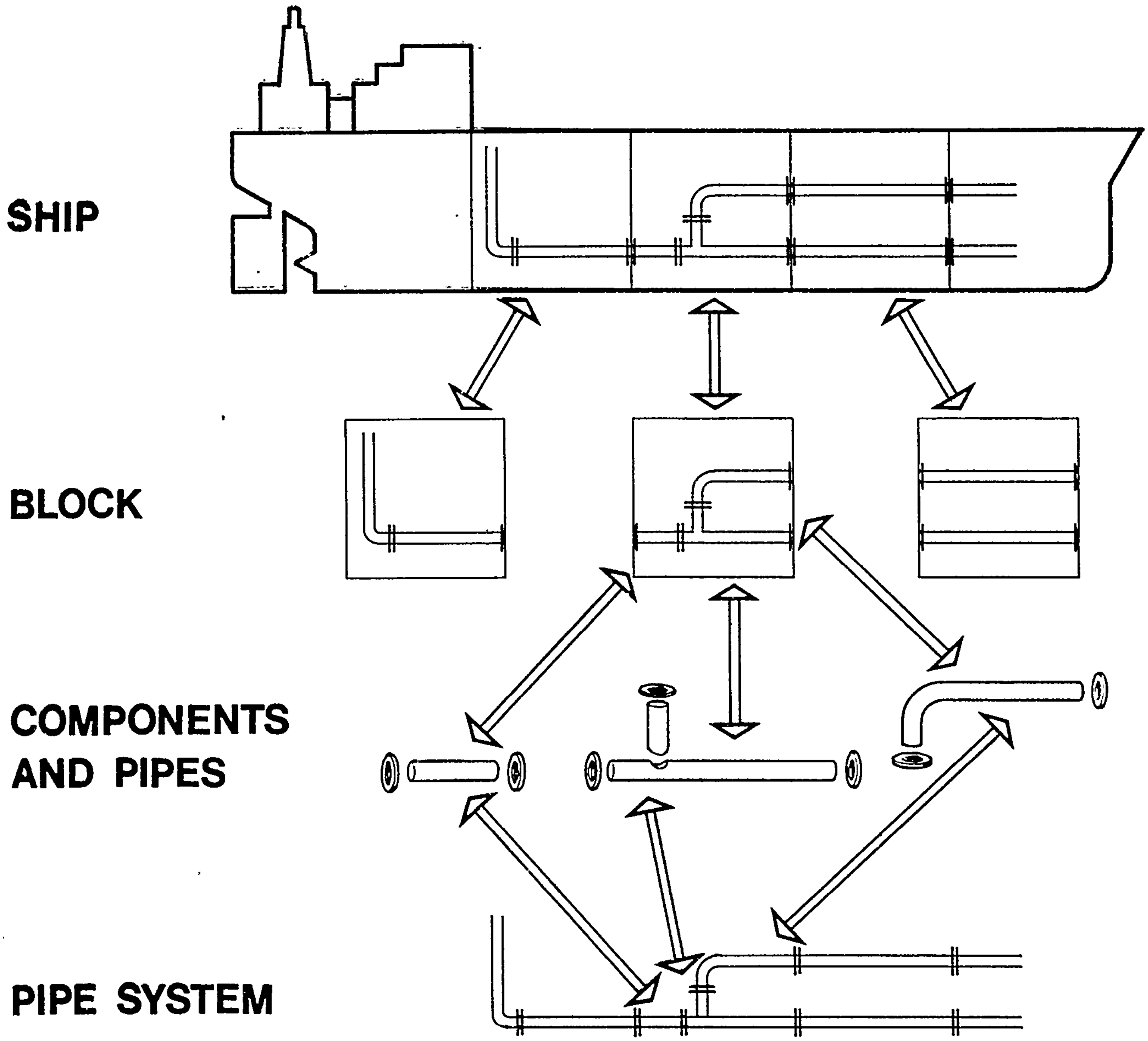
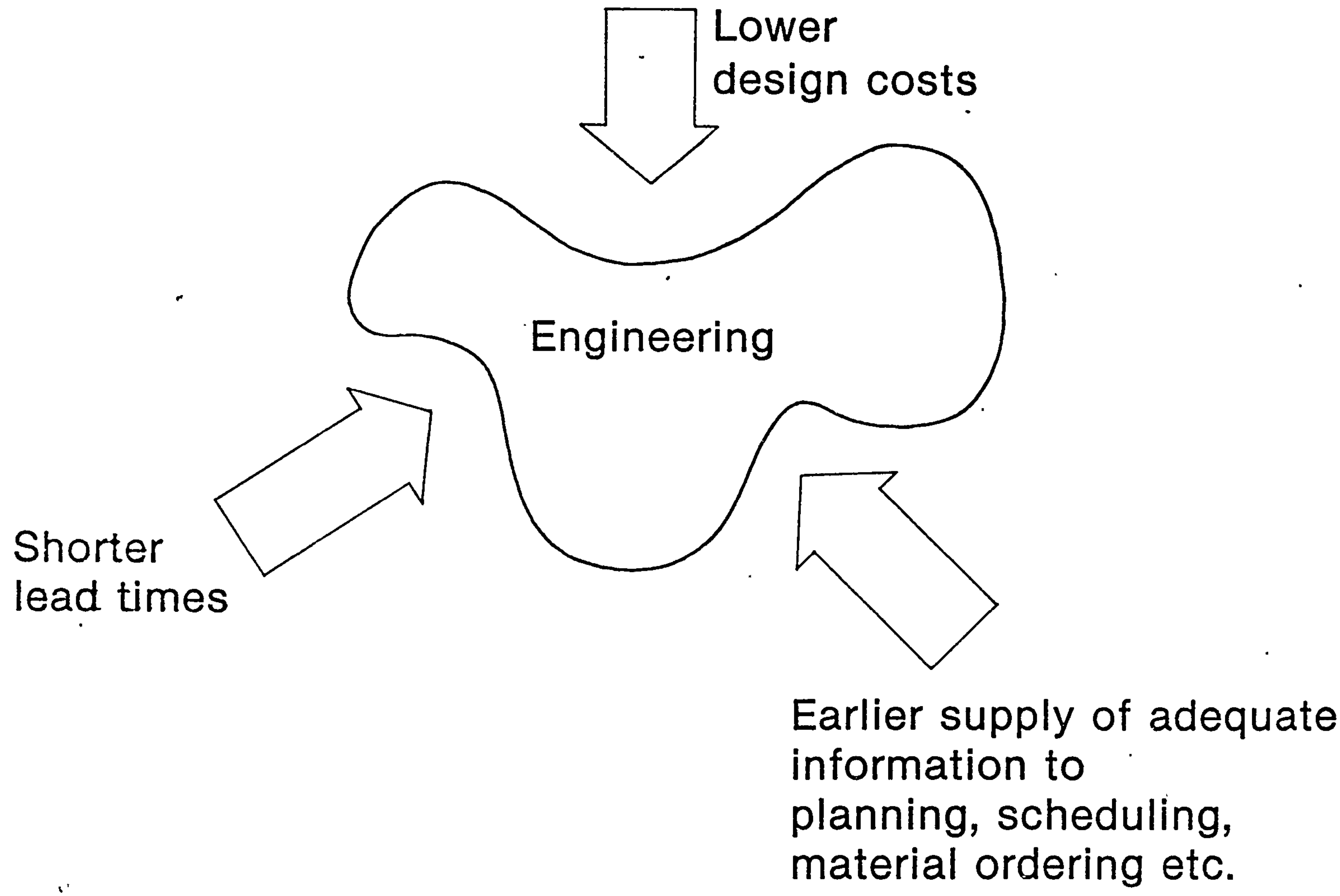
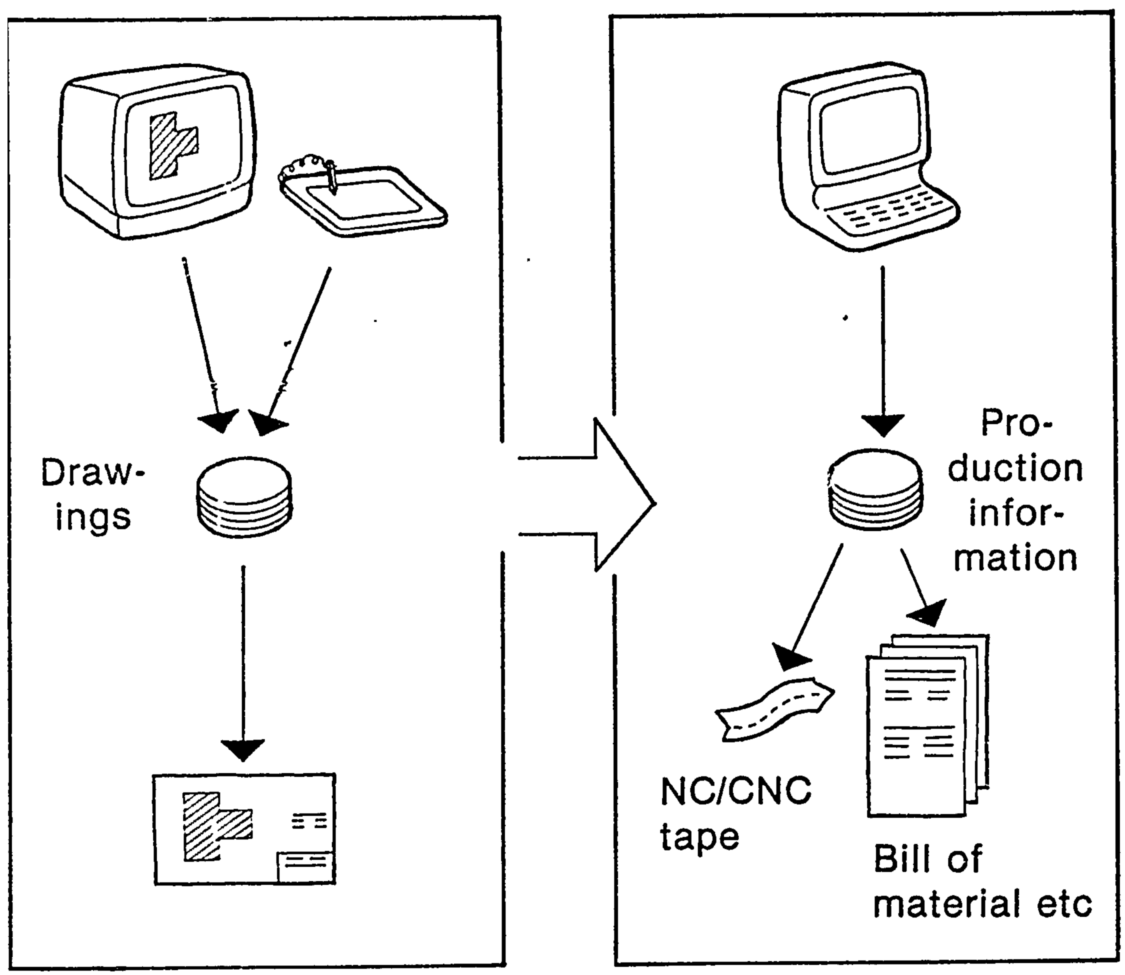
STEERBEAR PIPE
- Data Bank Structure



Requirements on Engineering



Computerized Drawing Oriented System

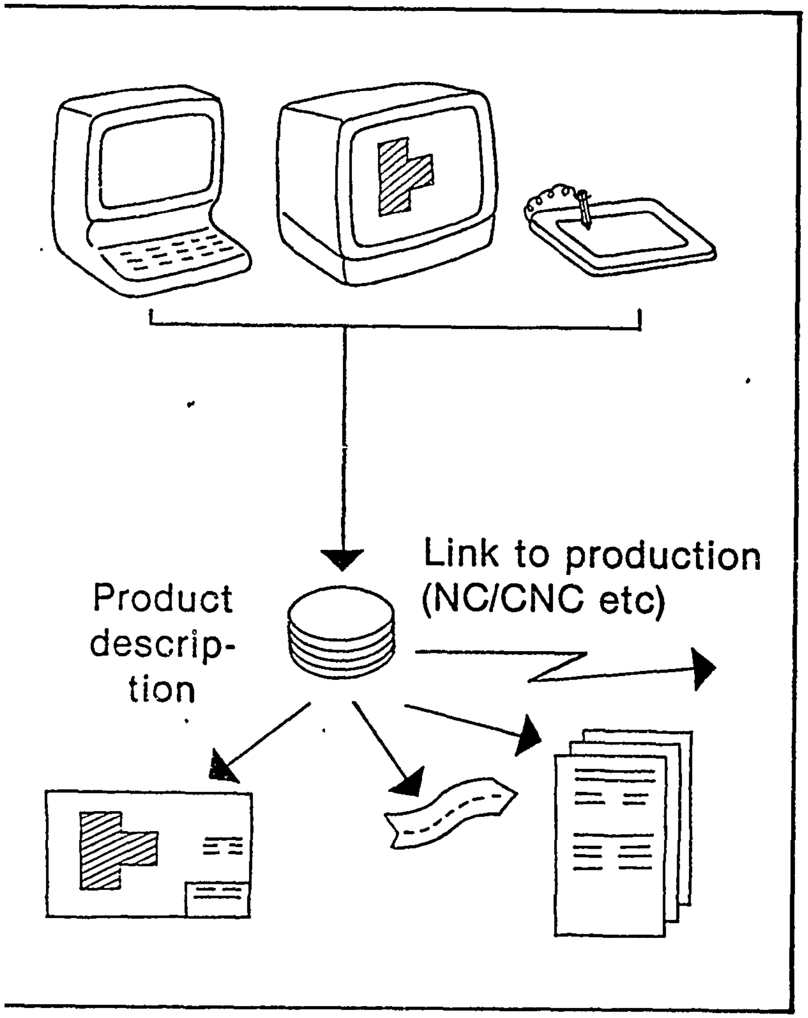


Two different systems or two isolated functions of one system

The product is repres-ented in the system as drawings.

Great efforts required to create production information.

Computerized Product Oriented System



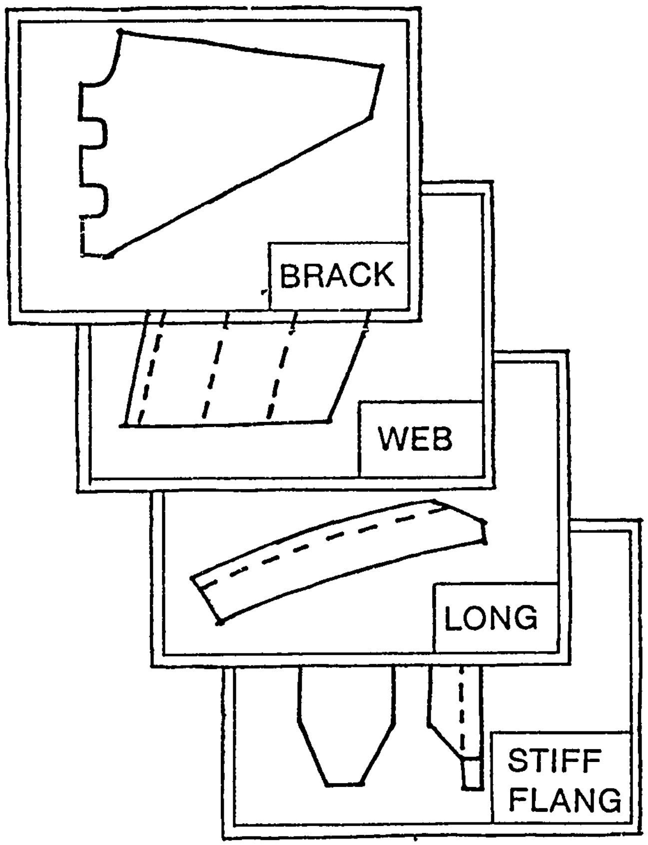
One integrated system with a common data base for all functions.

The product is represented in the system as a product description, ie a physical (in 3D) and functional description with connected administrative data.

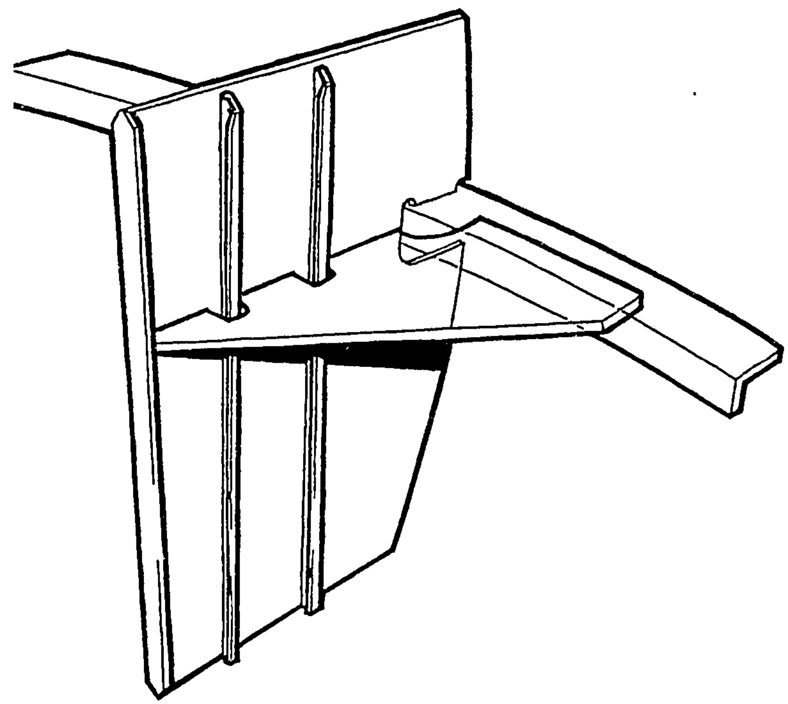
Drawings and other production information are derived from the product description.

Comparison

Drawing oriented system

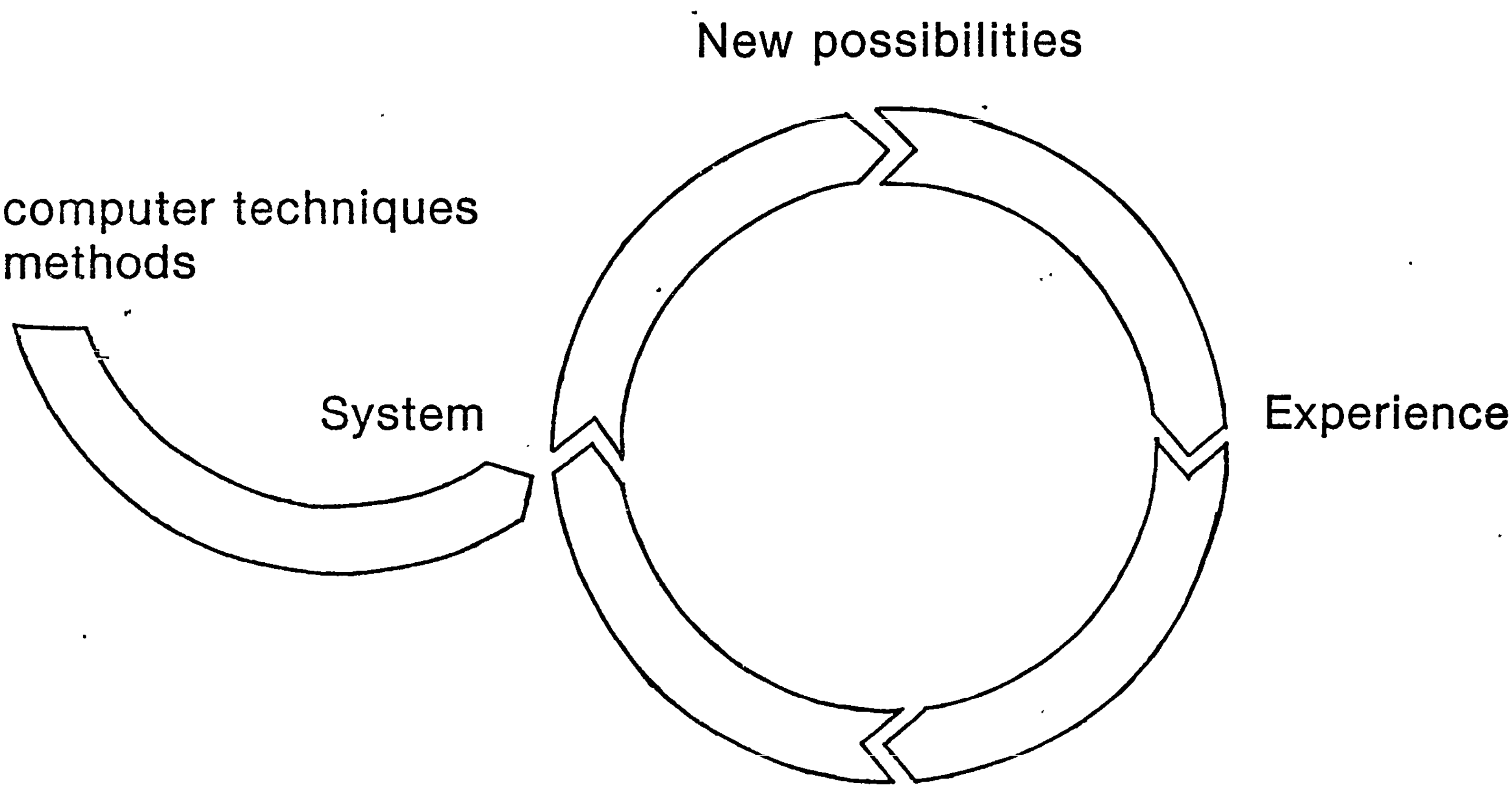


Product oriented system

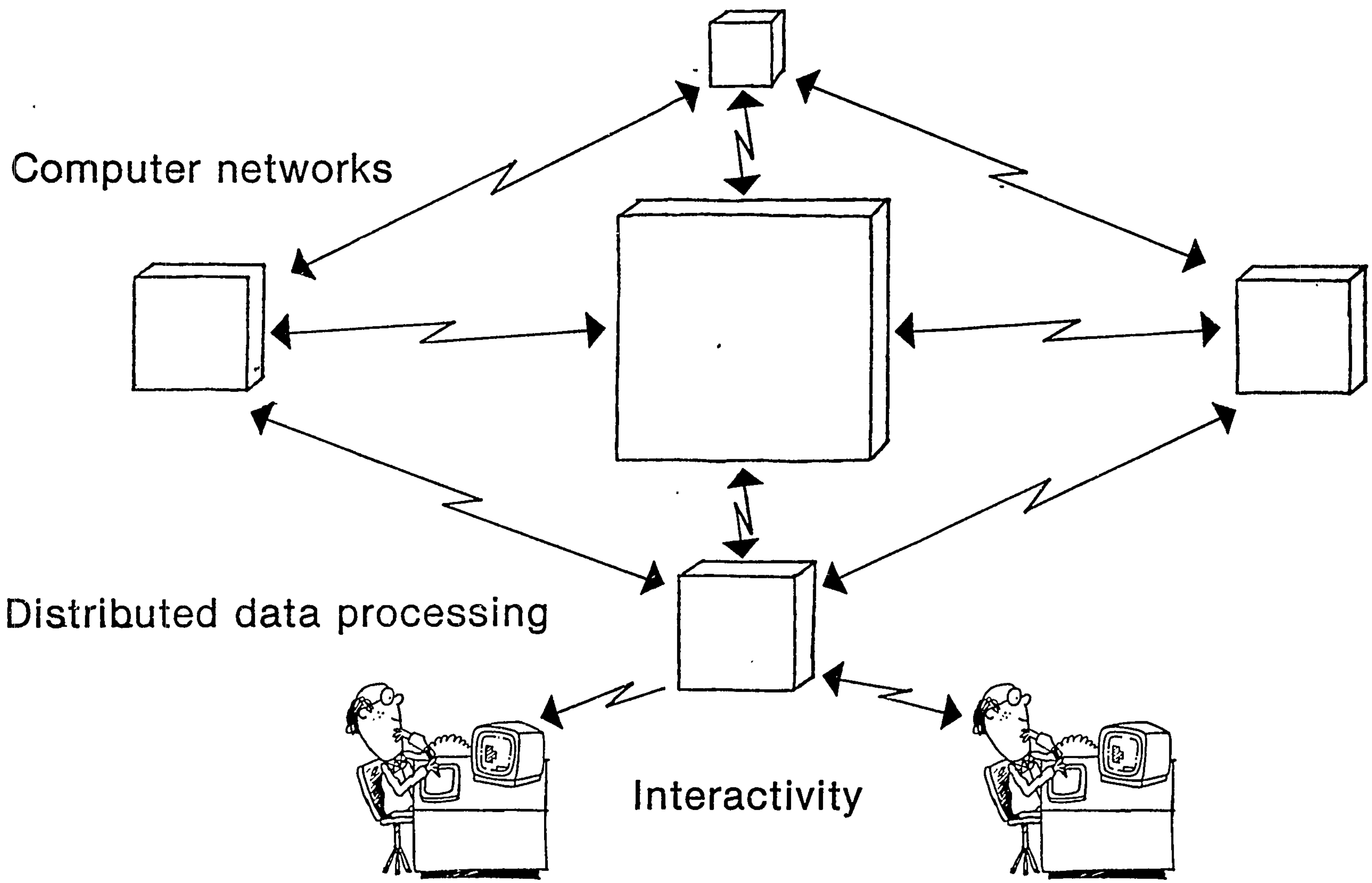


Why a New System?

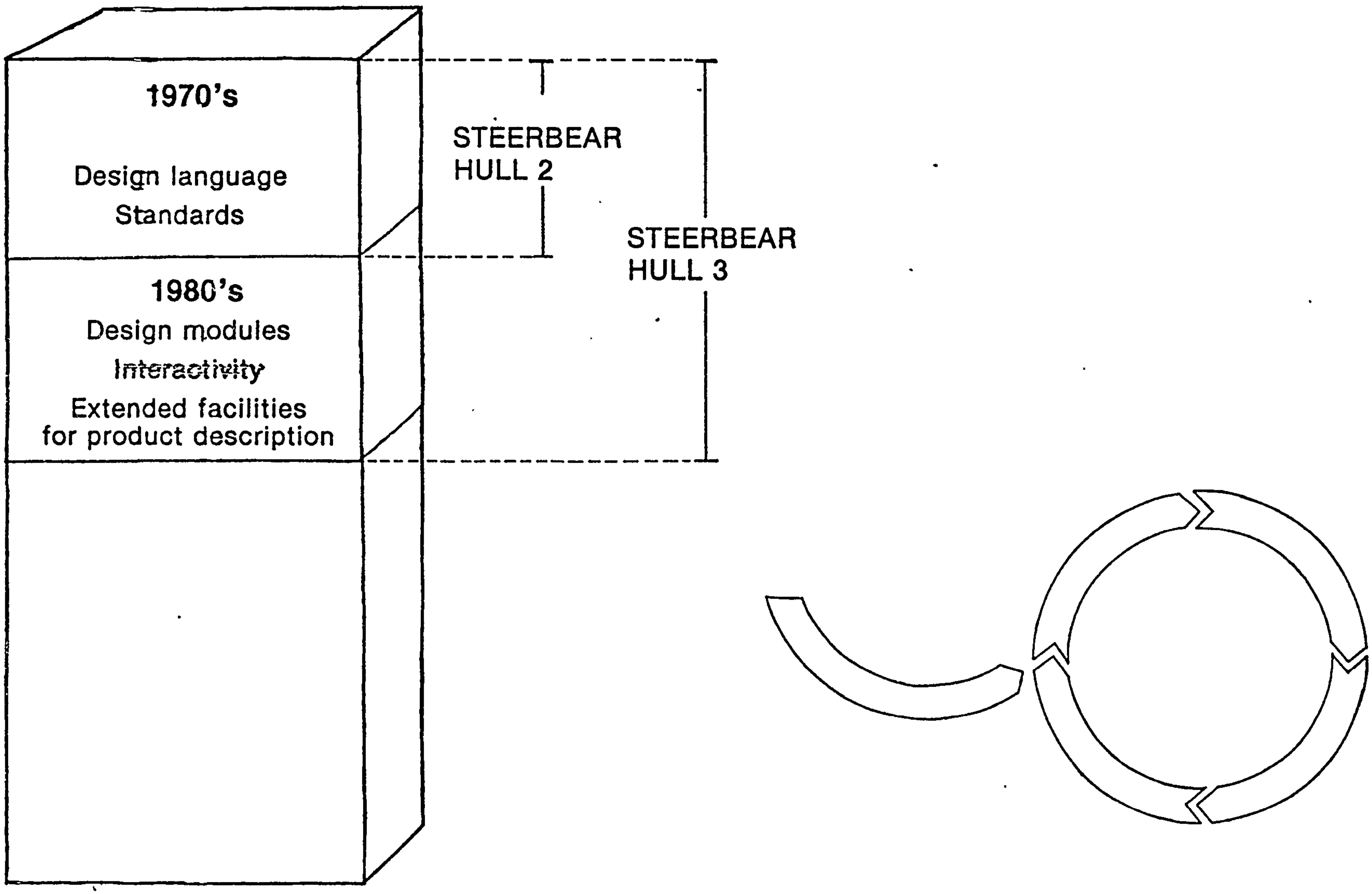
New computer techniques
New methods



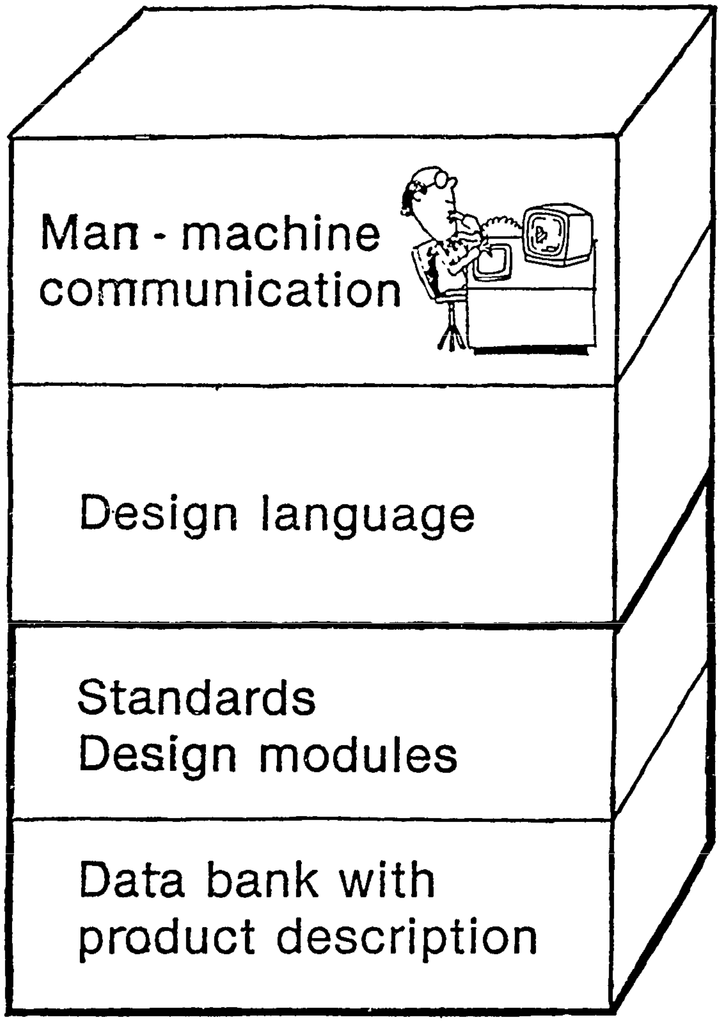
New Computer Techniques

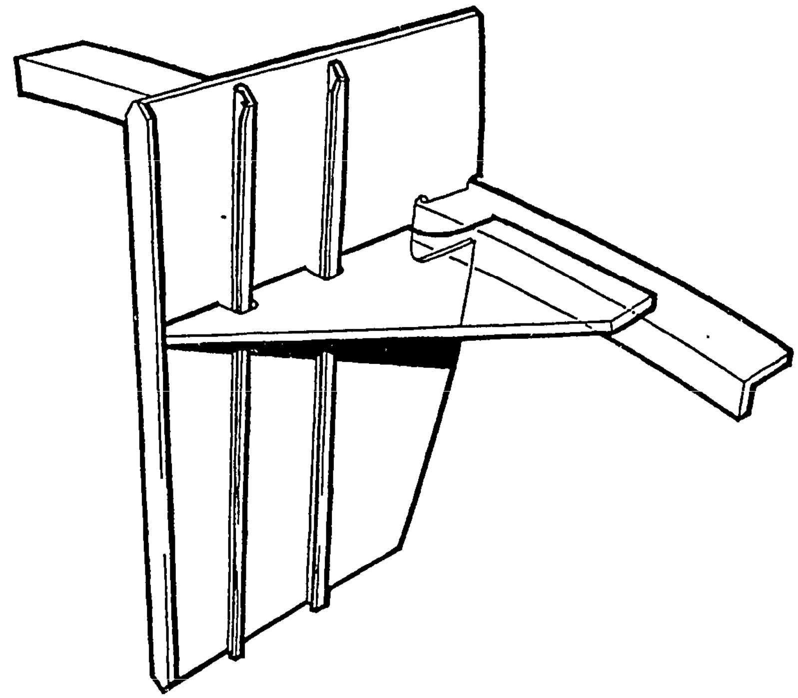


Engineering Workload Reduction



System Components

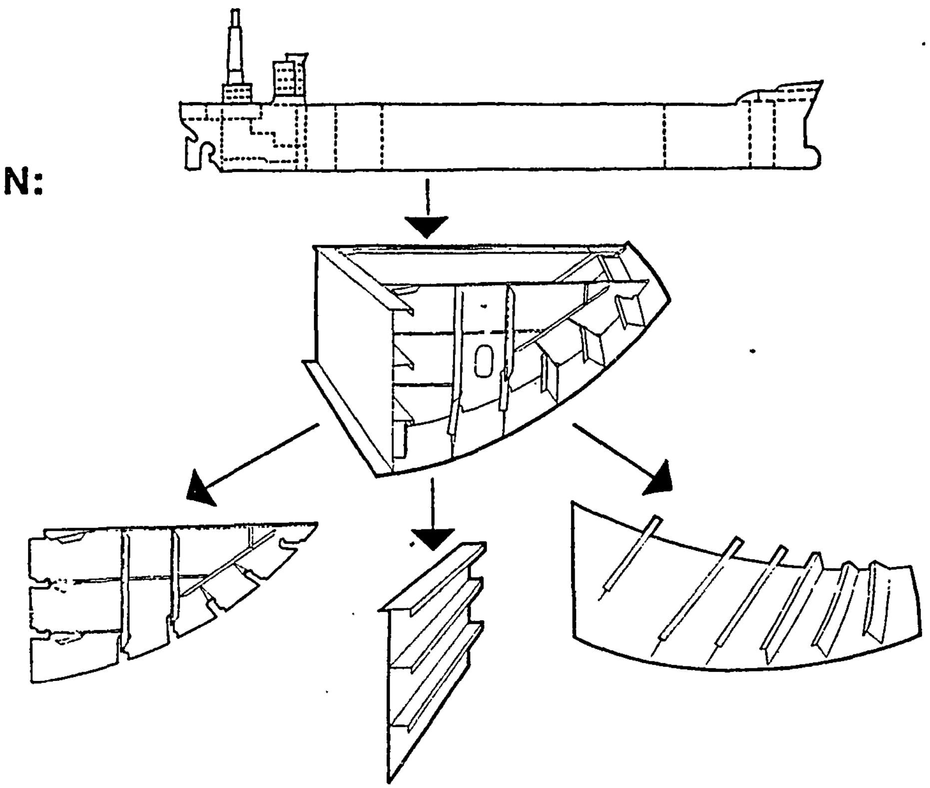




BRACKET, A, L27, AFT,
MTRL = 23, QUAL = B, POS = 124;

New Methods

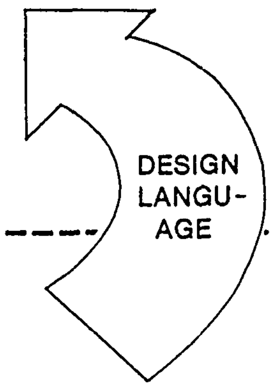
PRODUCT DESCRIPTION:



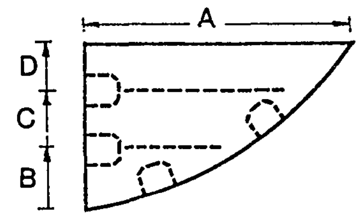
Units

Panels

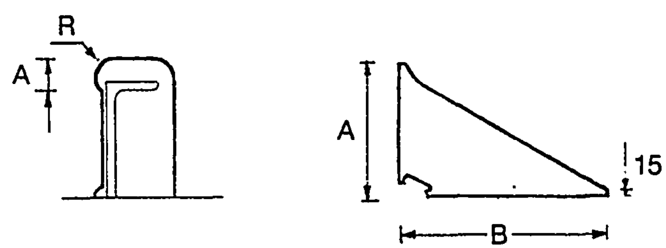
Absolute units, unique for each ship



RULES FOR:



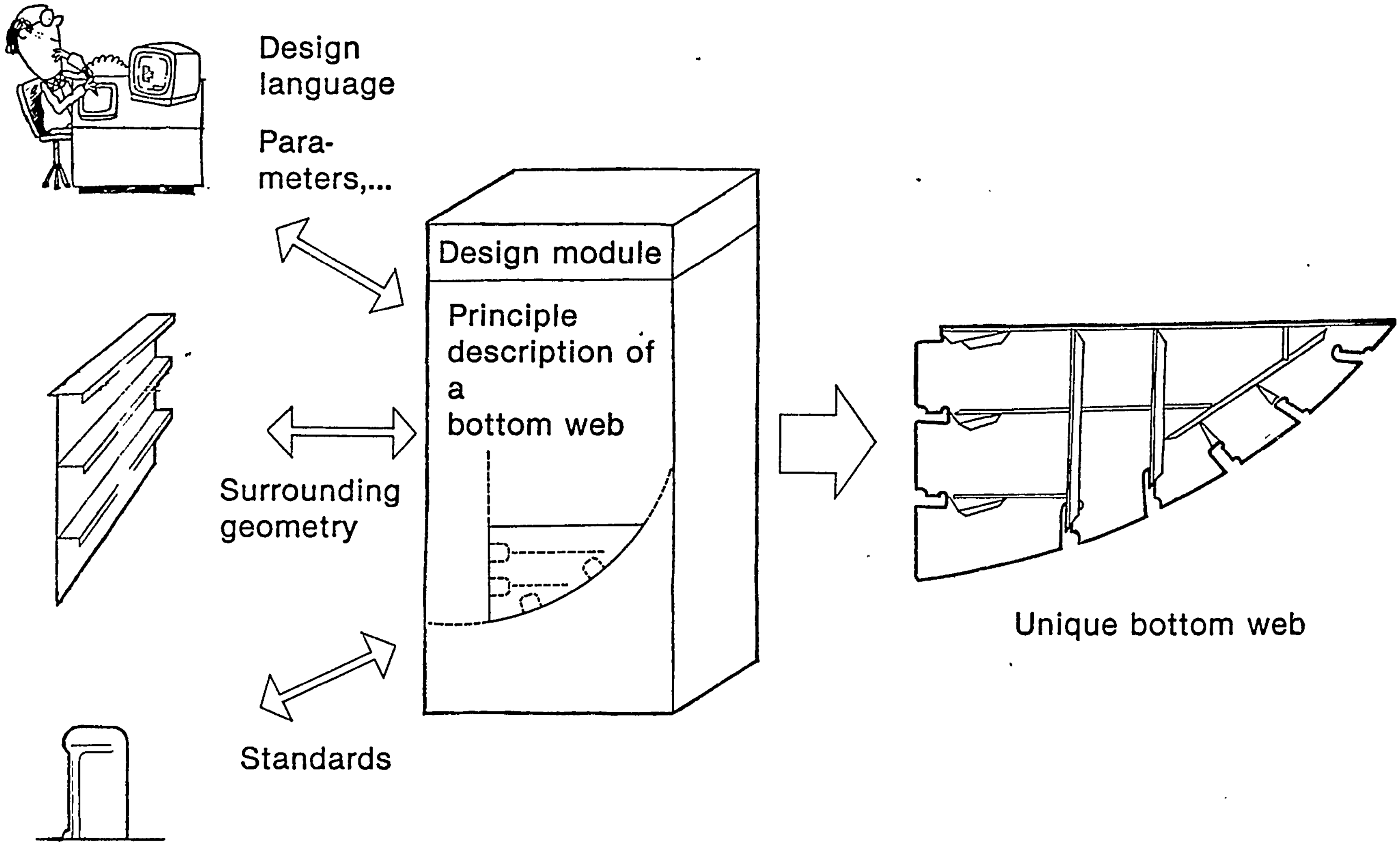
Design modules



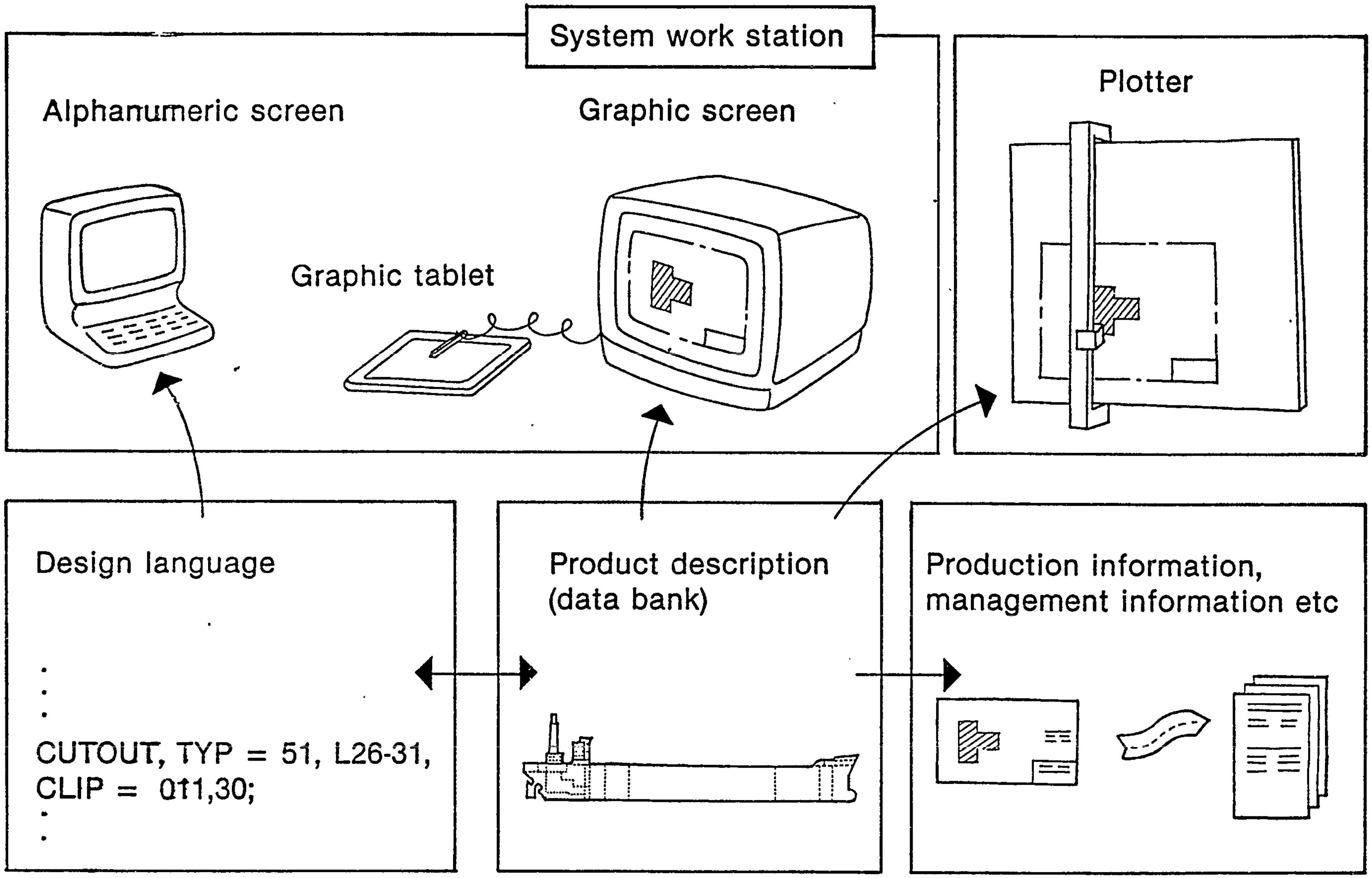
Standards

Parametric units, universal

Design Modules



System Concept

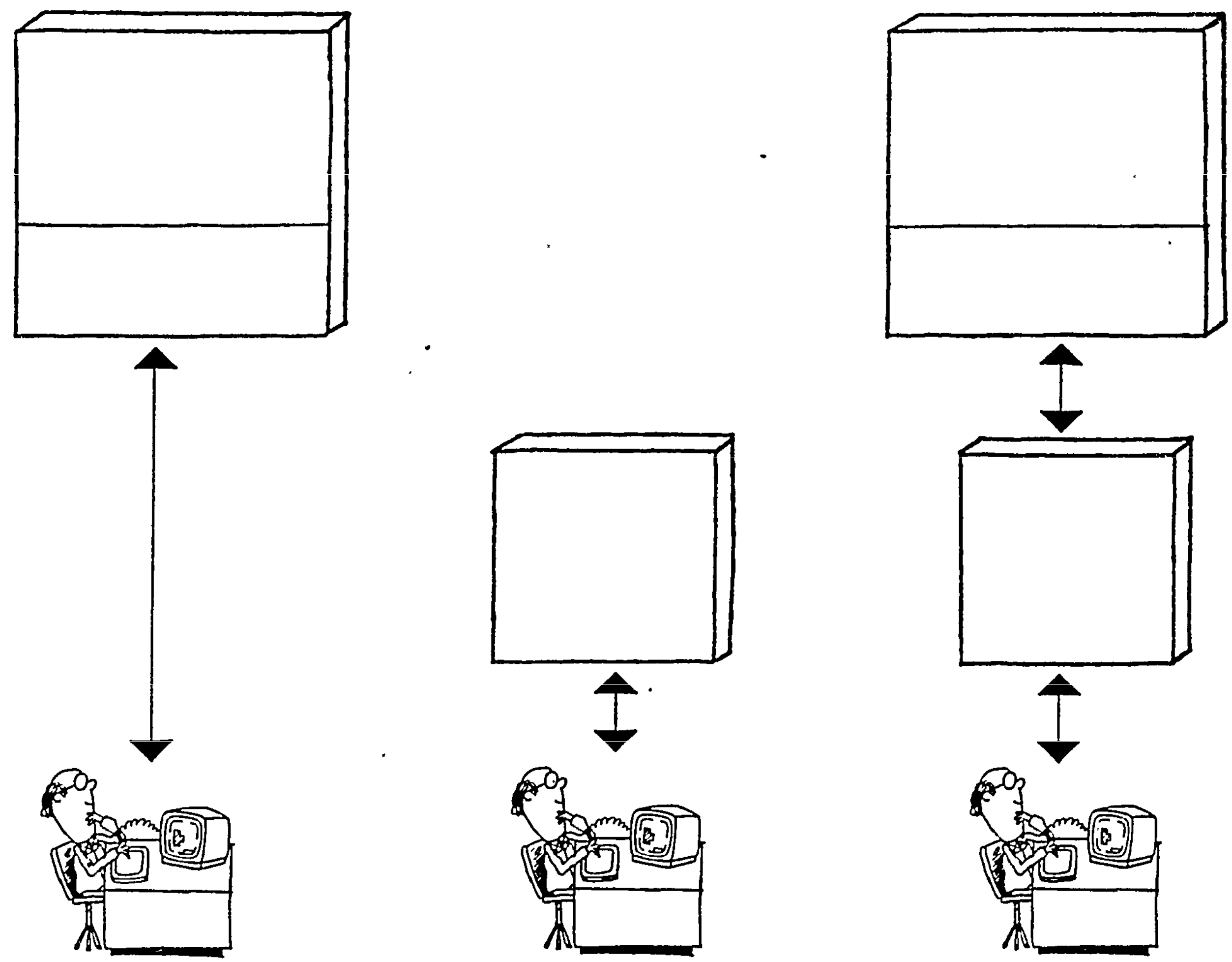


Hardware Configuration - Alternatives

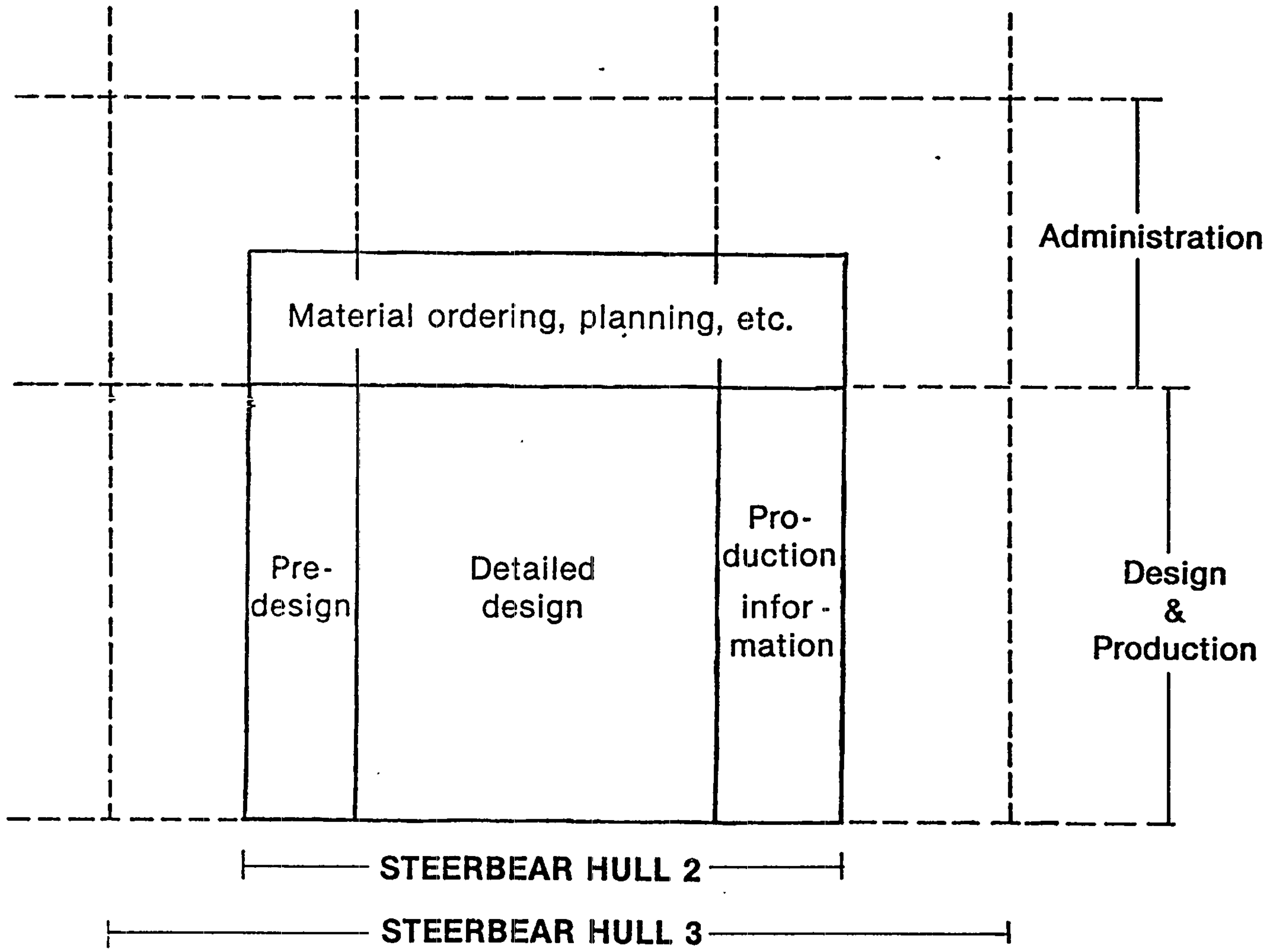
Main frame

Mini

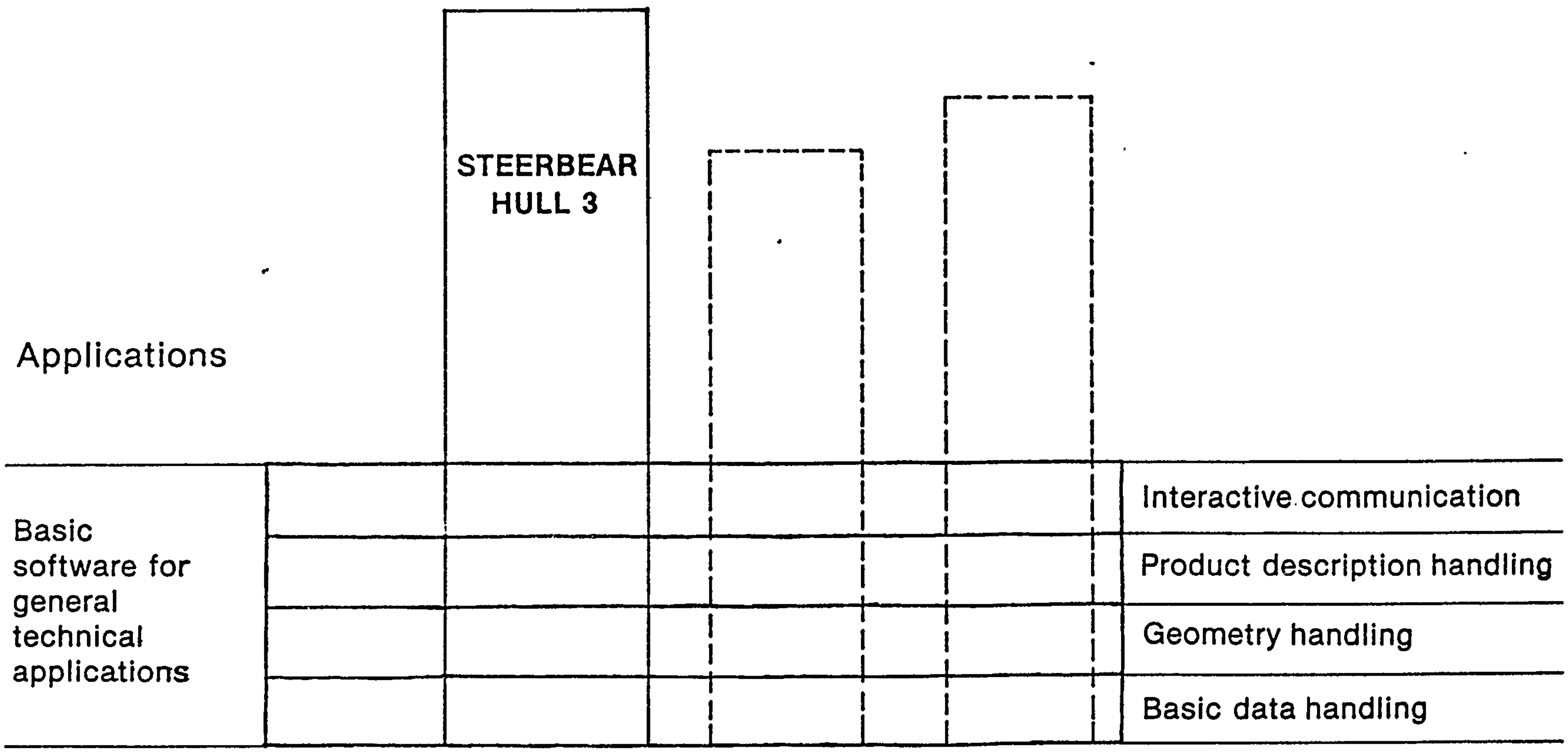
System
work station
incl. micro



New Functions in STEERBEAR HULL 3

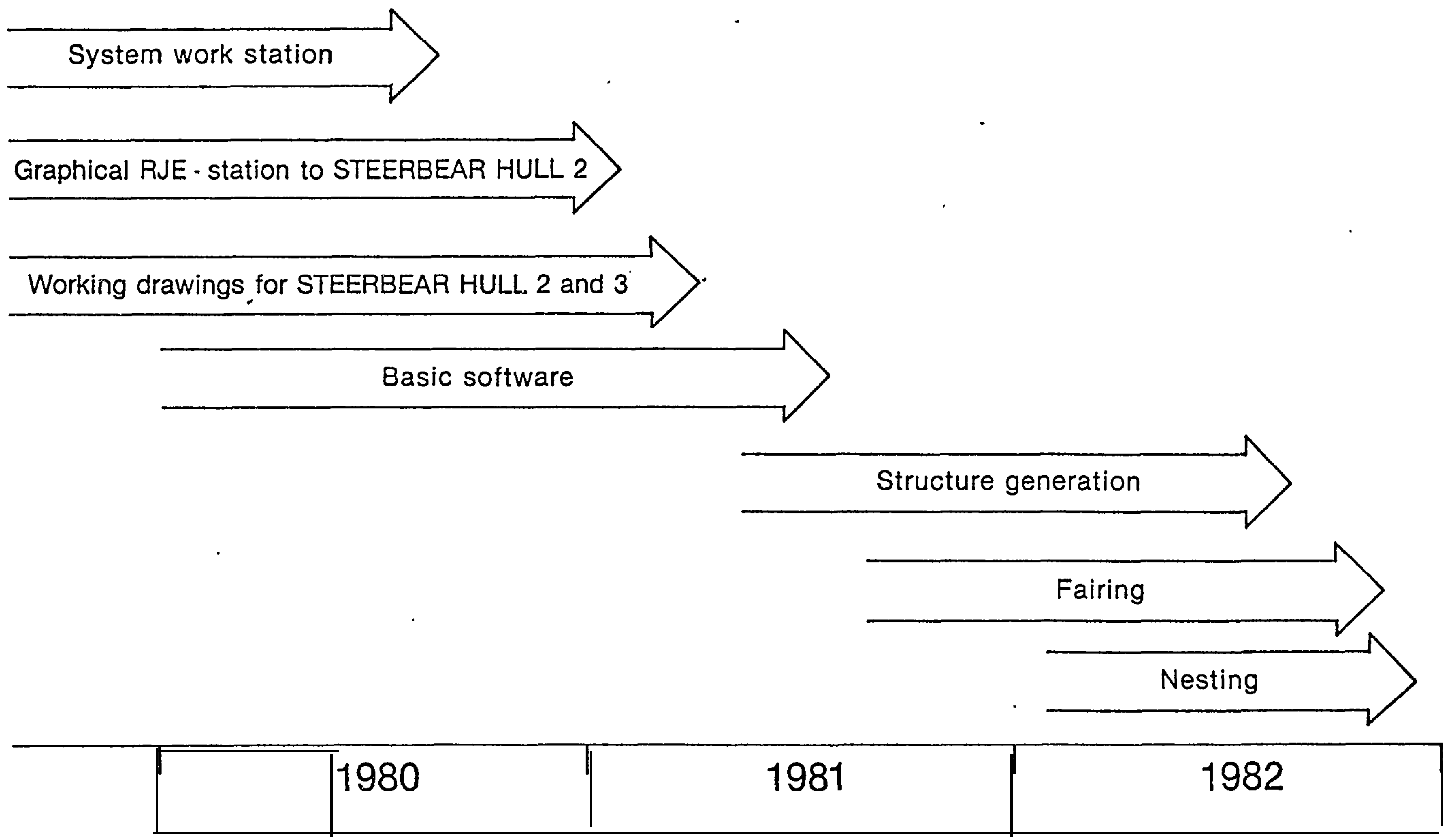


System Development



Implementation Schedule for

STEERBEAR HULL 3



ECONOMICS OF COMPUTERS IN SHIPYARD PRODUCTION CONTROL

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ABSTRACT

Private shipyards are under heavy pressure to improve productivity. So are the naval shipyards. Like the private shipyards, naval shipyards are focusing on improved production planning, scheduling, labor/progress data collection, and industrial engineering as the main thrust of their productivity improvement programs. Unlike the private shipyards, however, the naval shipyards are drawing heavily on the use of computers to support these functions. One project, the subject of this paper, is of particular interest since a computer is used to integrate planning, scheduling, work-in-process tracking and labor collection functions with engineered labor standards to provide a closed-loop production control system for a key production shop at the Portsmouth Naval Shipyard. This system achieved operational status during the spring of 1980. A complete economic history of its initial economic justification, development and operating costs and preliminary indications of payback are now available. Since the design of this system makes it quite appropriate for private shipyard use, the data included within this paper should be of interest to those concerned with the economics of computers in private shipyard production control functions. Results of this project are correlated with the objectives and results of the National Shipbuilding Research Program, as appropriate.

INTRODUCTION

The joint Maritime Administration/Industry National Shipbuilding Research Program has concluded that major improvements in shipyard productivity can be achieved by better planning and scheduling, by more accurate and reliable performance

measurement, and by more effective use of industrial engineering techniques - particularly engineered methods and labor standards. However, improvements in these four areas by themselves will contribute little to improving productivity. They must be cemented together in a closed-loop control system, with all its elements in balance and in tune with the production environment in which they must function. Failure to recognize and apply these basic principles will result in the expenditure of lots of money with little improvement to show for the investment.

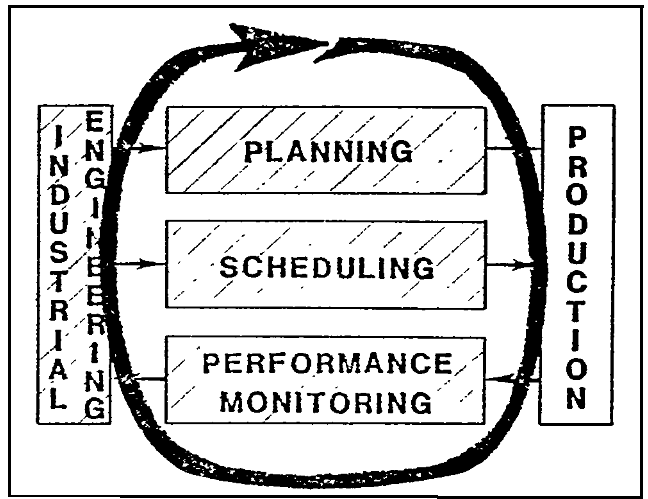

Figure 1. The Closed-Loop Production Control System

The subject of this paper is the development of a closed-loop system (Figure 1) for controlling operations of the Inside Machine Shop at the Portsmouth Naval Shipyard. Devel'opment of this system was justified on economic grounds. Initial results from six months of operational experience clearly substantiate the wisdom of the Portsmouth decision to proceed with the implementation of this system. Although the Navy has not been an active participant in the National Shipbuilding Research Program, findings of the experiment in the use of labor standards and closed-loop control at the Hardings steel fabrication plant of BIW[1] provided the basic economic justification for the Portsmouth venture.

THE BIW HARDINGS EXPERIMENT

The Bath Iron Works Corporation (BIW) postulated that one

[1] References listed at the end of the paper.

of the prime contributing factors to the high cost of constructing ships in U.S. shipyards was too much slack in construction schedules; furthermore,that this slack could be removed by the use of engineered labor standards. BIW also had the foresight to recognize that the imposition of labor standards would be pointless unless these were imbedded in a closed-loop system that would measure actual performance against standards in order that proper and effective action could be taken when necessary.

The Maritime Administration and the Ship Production Committee of SNAME endorsed testing of engineered standards and closed-loop control in a live production setting. BIW then included in its Ship Producibility Research Program a research task (Task O-2) to investigate the application of engineered standards and closed-loop control toward reduction of fabrication costs in the Hardings Plant. The results[1] from this limited experiment were dramatic. Adherence to schedule was improved (Figure 2) from an average of 3.2 weeks late to zero weeks late. Steel fabrication costs (Figure 3) were reduced by twenty percent.

Claims to improvements of this magnitude are naturally suspect and usually require confirmation before anybody takes them seriously. A moments reflection on this experience, though, suggests that the results of the Hardings experiment are not unreasonable at all, but rather what we should have expected.

There is, in fact, a lot of slack in ship construction/overhaul schedules which we must learn to eliminate. As Lou Chirillo has pointed out[2], each day squeezed out of a construction schedule is equivalent to saving $20,000 in interest on the money to finance work-in-process. Although the naval shipyards are not confronted with construction financing costs, they do recognize the fact that shortening the length of an overhaul saves money. In the case of submarines, each day pared off an overhaul saves between

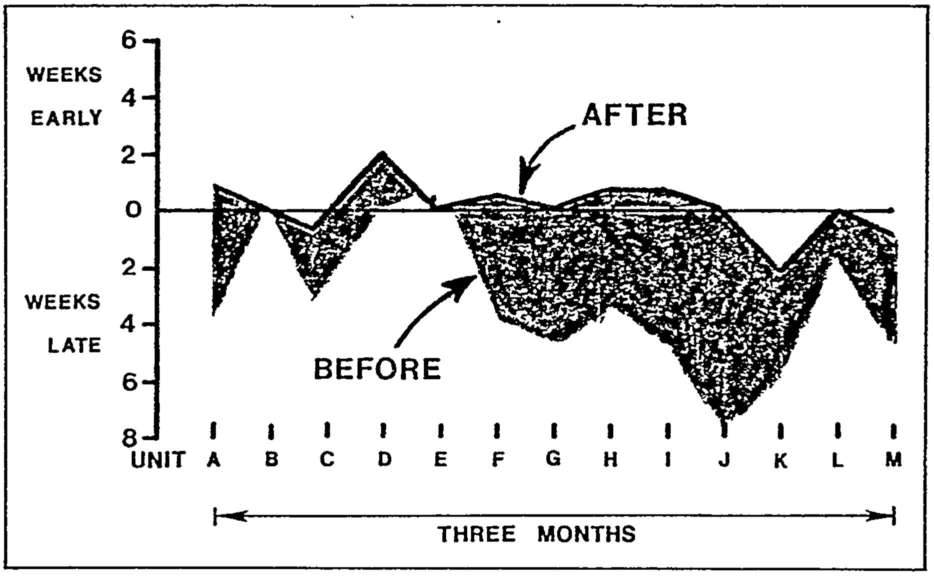

Figure 2. Improvement in Adherence to Schedule[1]

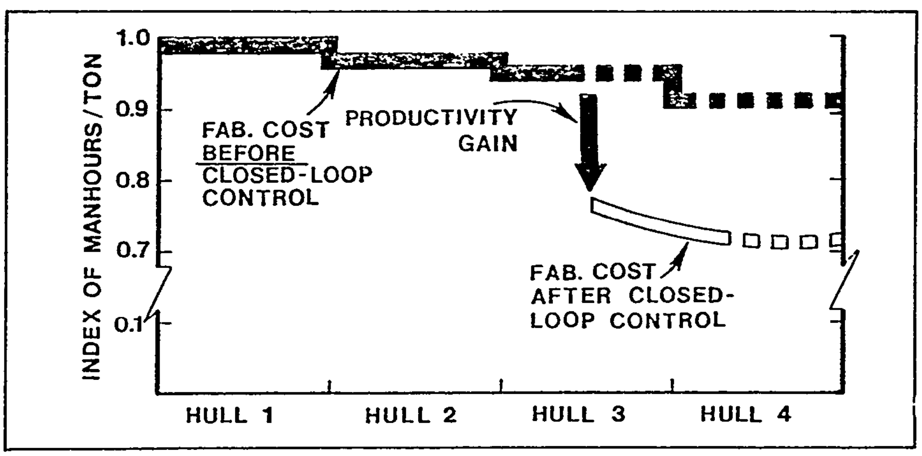

Figure 3. Reduction in Fabrication Costs[1]

$50,000 and $100,00. So reducing the duration of a construction or overhaul project by only a few days can still save a lot of money.

These two data points strongly suggest that one important way of reducing construction/overhaul costs is to compress construction/overhaul times[3] We all know, however, that if schedules are compressed too far, then costs tend to grow because of overtime, re-work, interference, delay and disruption from late material and late drawings, etc.

Cost of construction or overhaul as a function of time, therefore, forms a cup-shaped curve, (Figure 4A), where both expediting costs for excessively short schedules and investment costs for excessively long schedules tend to drive costs above some minimum.

Results of several projects within the National Shipbuilding Research Program[4] support the hypothesis that the U.S. shipbuilding industry tends to operate in the region of excessively long construction periods (Figure 4B). cost profiles for naval ship overhauls tend to be like that shown in Figure 4C. Early phases of an overhaul tend to drag; later phases entail high expediting costs in order to finish on schedule. In both cases there are significant opportunities for reducing costs (Figure 4D). How are these opportunities to be exploited? By getting both slack and congestion out of the flow of work. How can this be done? By controlling work at the right level of detail.

FINDING THE RIGHT LEVEL OF DETAIL FOR CONTROL OF WORK

What is the right level of detail? It is the level that minimizes congestion and eliminates unnecessaly slack which, in turn, depends on the nature of the work and the working environment.

The subject of this paper is a system now operating in the Inside Machine Shop of the Portsmouth Naval Shipyard.

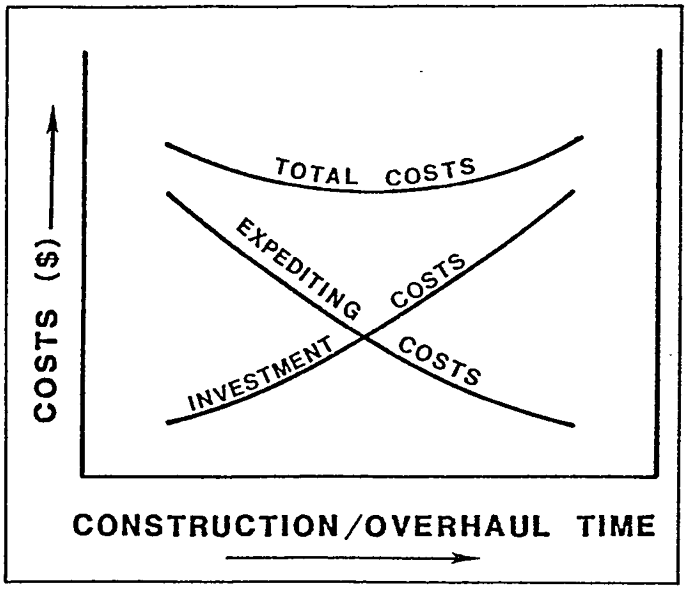

Figure 4A. Construction/Overhaul Cost/Time Relationship

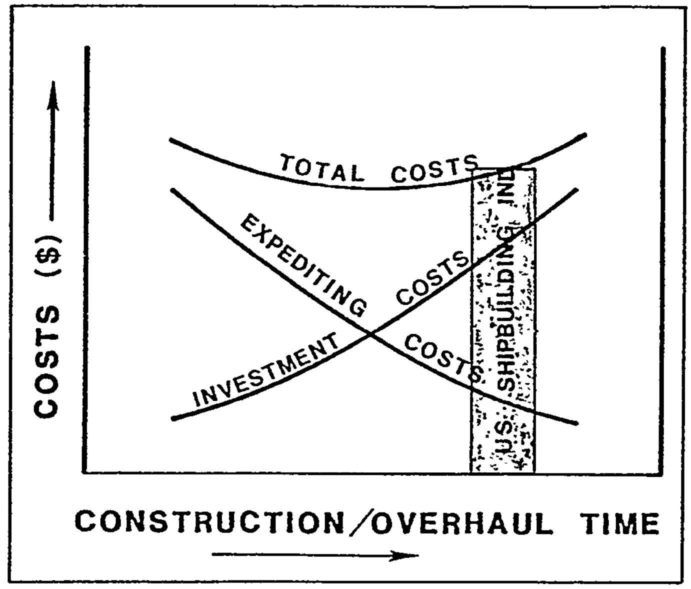

Figure 4B. Cost/Time Posture of U.S. Shipbuilding Industry

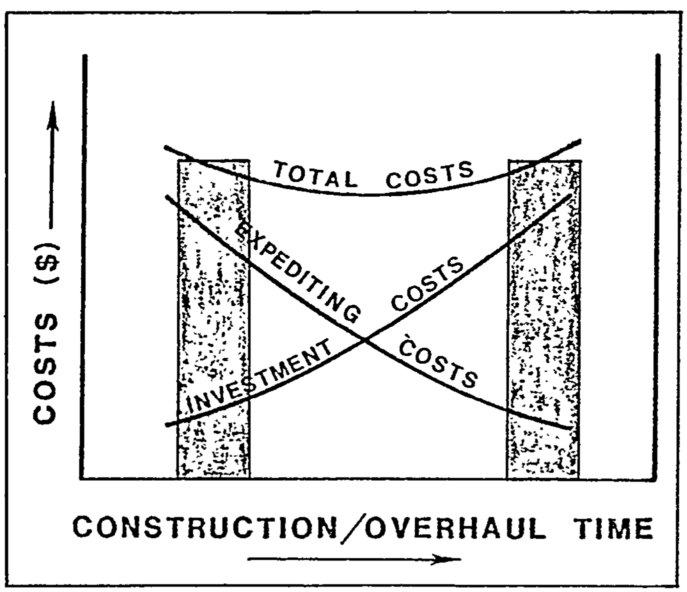

Figure 4C. Cost/Time Posture of Overhaul Work

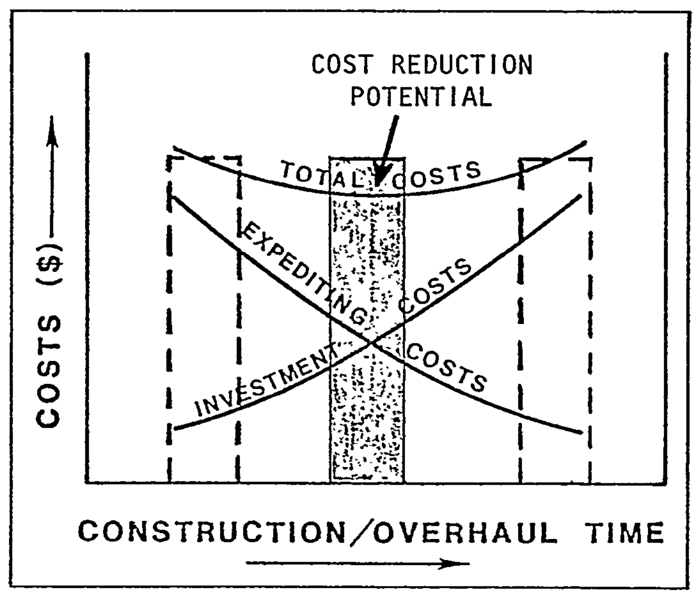

Figure 4D. Cost Reduction Potential Through Management of "Time"

Virtually all of the work in this shop involves the refurbishment and repair of components, like valves, actuators, pumps, shafts and bearings, used in submarines. To understand the structure of the work within this shop and its production control problems, we should know a little bit about what is involved in overhauling submarines.

A typical overhaul (Figure 5) costs between $50 and $100 million, depending upon type and class, and consumes between 1.5 and 2.5 million man hours. Eighteen months is the target overhaul time period, but most take somewhat longer - some as long as two years. As a point of reference, a new RO/RO will cost about $75 million and a new 35,009 DWT tanker about $50 million. In terms of the size and cost of the work package, overhauling a submarine is roughly equivalent to constructing a commercial ship.

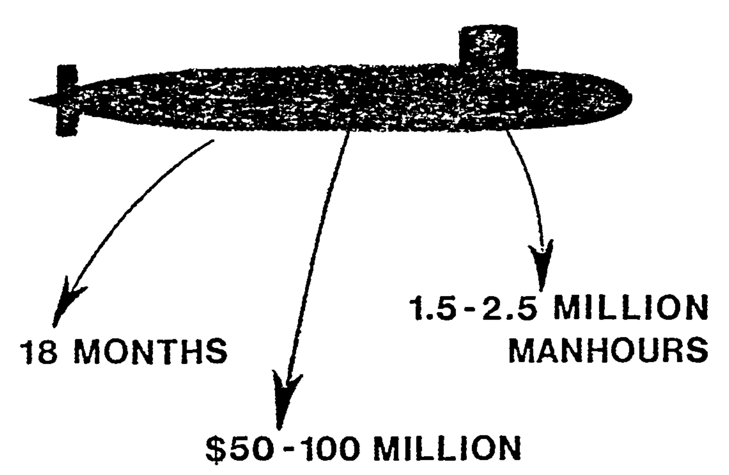

Figure 5. Submarine Overhauls

There are about 50 to 60 productive cost centers (that is, shops, departments, etc.) within the shipyard that provide direct support to submarine overhauls. Distribution of work between these various work centers for an overhaul is shown in Figure 6. The pipe, outside machine and inside machine shops have been separately identified in this figure because these three shops really control the overhaul duration and cost, although they contribute collectively only 20% of total direct labor.

Pipe and outside machine shop work is conducted largely aboard the submarine, whereas the inside machine shop treats

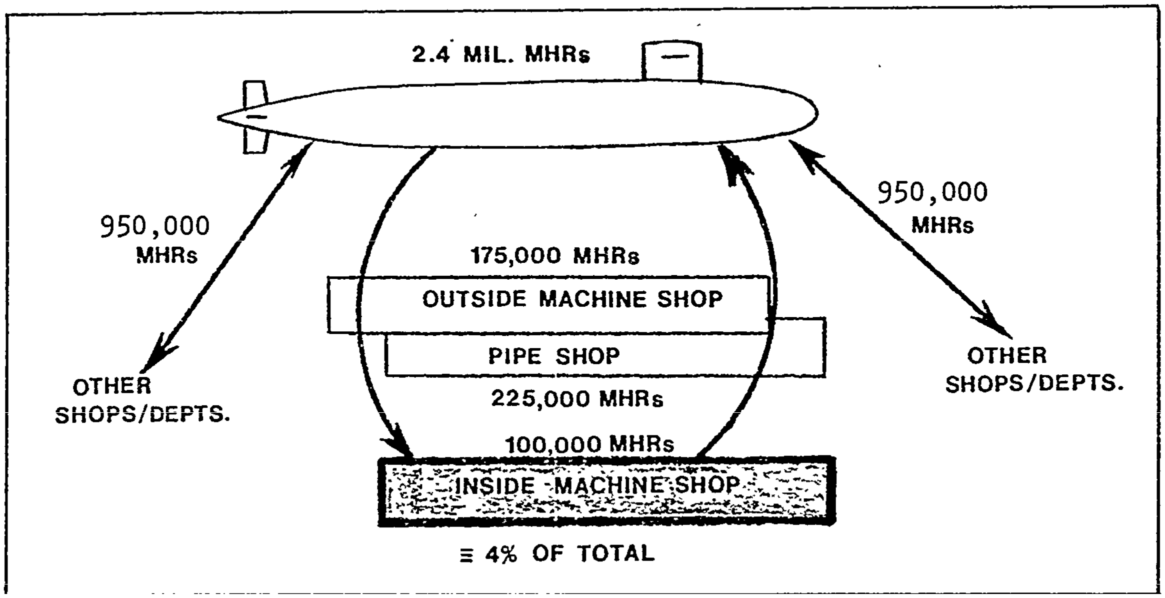

Figure 6. Distribution of Labor for Submarine Overhauls

components removed from the submarine by the other two shops. The flow of overhaul work, therefore, begins with removal of components from the submarine by the outside shops. Components are shipped to the inside shops where they are repaired and refurbished. The components are then shipped back to the outside shops for reinstallation and test.

The test phase of an overhaul is complex and takes many months. Components are tested individually; then in combination; then as sub-systems; and finally as entire systems under various anticipated operating conditions.

Shipyard performance during the reinstallation and test phases of an overhaul (which actually comprise over 50% of the overhaul duration) are critically dependent on Shop 31 (the inside machine shop) meeting component delivery schedules. Shop 31's schedule adherence problem is complicated by the fact that the last components removed from a submarine are usually the first to be reinstalled to avoid interference problems. These components appear on the Shop 31

receiving dock when the shop is already fully loaded. Unless they are given special scheduling treatment, they will invariably be completed late.

Shop 31 performance has, therefore, a direct impact on the cost and duration of a submarine overhaul -- even though it contributes only 4% (Figure 6) of the labor total.

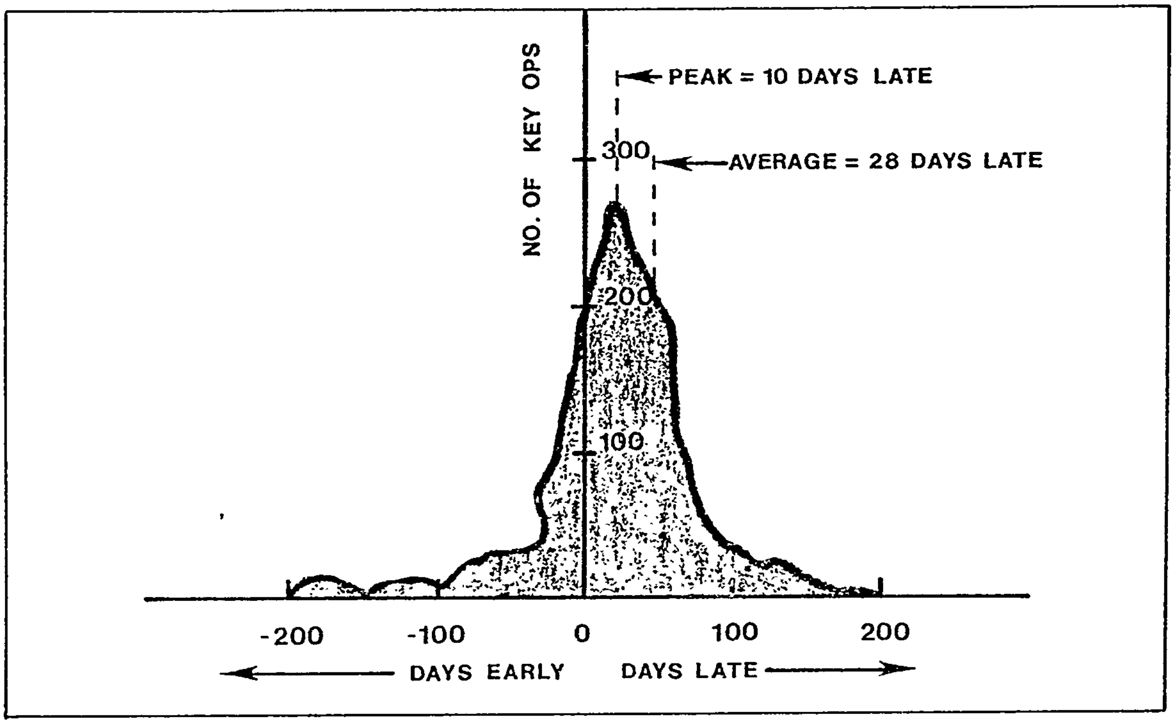

Figure 7. 1976 Performance-To-Schedule Profile of Shop 31

What has Shop 31's performance to schedule been? Not exemplary as can be seen from Figure 7. This distribution represents a sample of about 1300 jobs worked by the shop during 1976. For reasons stated in the BIW Manual on Production Oriented Planning[3], the spread of this distribution is really of greater concern than the average lateness of twenty-eight days, because the spread indicates that the "production control system" is not really exerting much control.

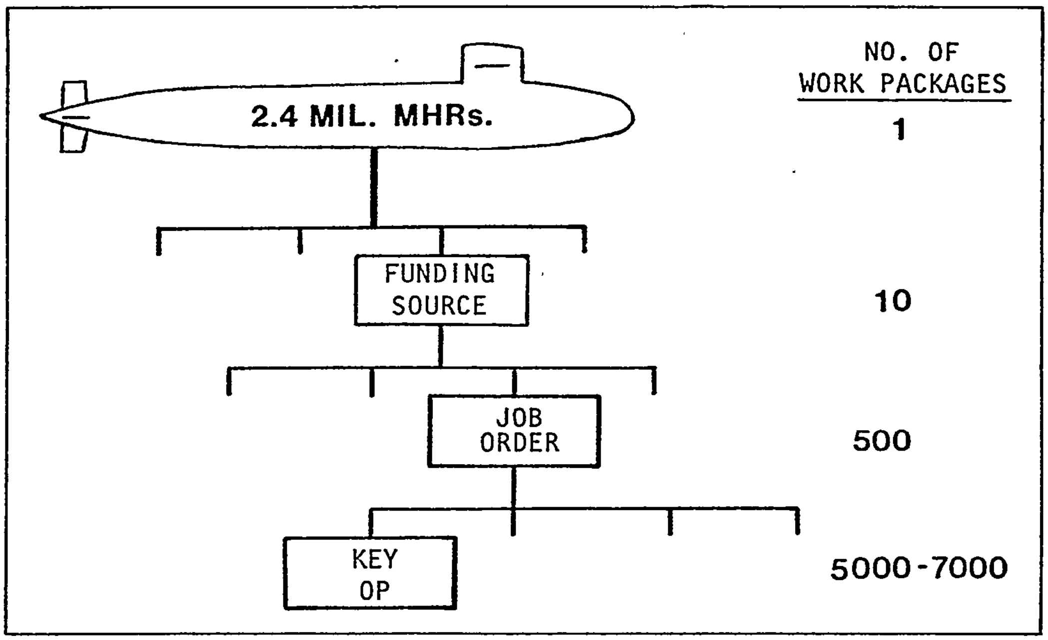

Figure 8. Work Breakdown Structure for Submarine Overhauls

The naval shipyards, since the early 1970's, have used a centralized, batch ADP system-to assist the central planning, production, supply and financial functions. To facilitate control of overhaul work and the collection of material and labor expenditure data, these shipyards have adopted the standard work breakdown structure shown in Figure 8. The Key OP, or more properly Key Operation, is the work package that is issued to the shops. It both specifies the work to be accomplished and authorizes its accomplishment. Key Op records within the central ADP system are used to collect material and labor expenditures, and to track progress against scheduled completion dates. In size, Key Ops average 300 to 400 man-hours. The Key Op,then,is the basic vehicle for planning and scheduling work and for monitoring shop performance.

Work is issued to Shop 31 from central planning in the form of Key Ops. A single Key Op will cover, on the average, repair of about 3 components, but may cover as many as 100 or as few as one (Figure 9). Within Shop 31, repair of each

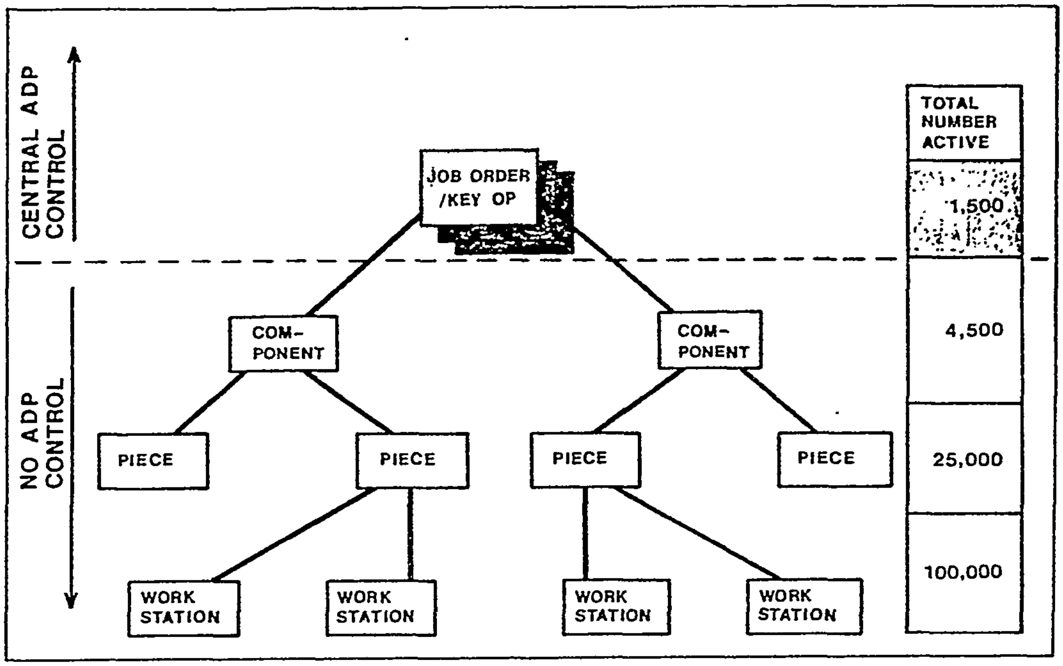

Figure 9. Work Breakdown Within Shop 31

component must be treated separately since each **item** removed from the ship must be reinstalled (or a replacement installed), and the reinstallation must be documented and certified. In point of fact, within the pipe, inside machine, and outside machine shops, work is focused on the handling of single components and their constituent parts -- not on the parent Key Op. But as shown in Figure 9, controlling work at the component level involves tracking the status of literally tens-of-thousands of items. This is a prodigious task.

The schedule performance of Shop 31 (Figure 7) can be traced directly to the fact that the shop was never allowed the where-with-all to control operations at the level required -- namely, at the component level. Historically the shop has been overwhelmed by the shear numbers of items and activities it had to track; it had neither the facilities nor the people to keep matters under control. Virtually the entire shop office staff was involved in planning and issuing jobs; people were not available to close the control loop (Figure 10).

On the basis of these facts, it was concluded that shop performance could be improved only if control was extended to the component level. Even so, there was still a legitimate and important management question whether control should actually be established at this level. To answer this question in a reasonable way an analysis of the economic factors involved was required.

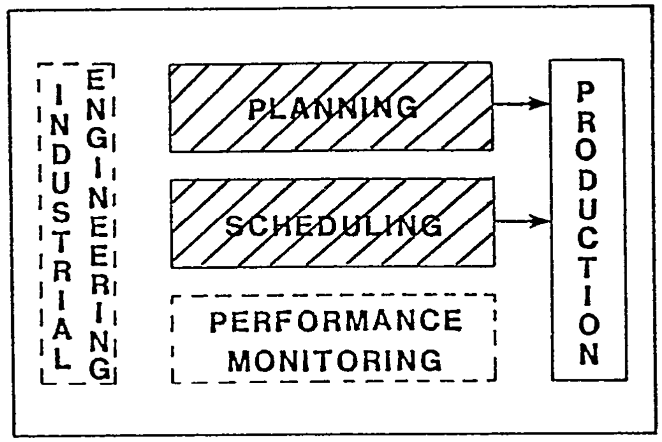

Figure 10. The Shop Control System in 1976

General speaking, breaking down the work into smaller and smaller work packages permits tighter control. Tighter control permits more precise scheduling which, in turn, reduces congestion and eliminates slack. Elimination of slack permits compression of the overall schedule which saves money -- as we noted earlier.

Increasing control can reduce cost as shown in Figure 11A. However, there comes a point in work package division where all of the savings have been captured. Further subdivision of the work beyond that point does not contribute any further savings, so the curve flattens out.

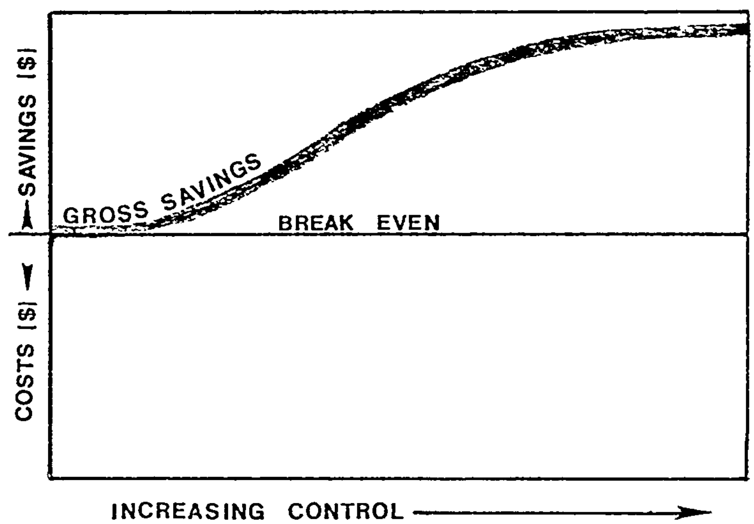

Figure 11A. Savings From Increased Control

In this world, we never get something for nothing; we have to pay for increased control (Figure 11B) -- for people, for paper, for equipment, for telephones and desks for the people, etc. The slope of the curve increases with more detailed control because the number of work packages usually increases exponentially with the number of levels in the work breakdown structure (Figure 8). To find out whether increasing the level of control is sensible requires subtracting the expected costs from the expected savings (as we have done in Figure 11C) to find out whether increasing the level of control costs more than it saves. As long as the level of control lies to the left of the shaded bar, every dollar spent in increasing control is more than recovered in the returned savings. When the level of control is to the right of the shaded bar, every additional dollar spent in increasing control yields less than a dollar in return. The right level of detail

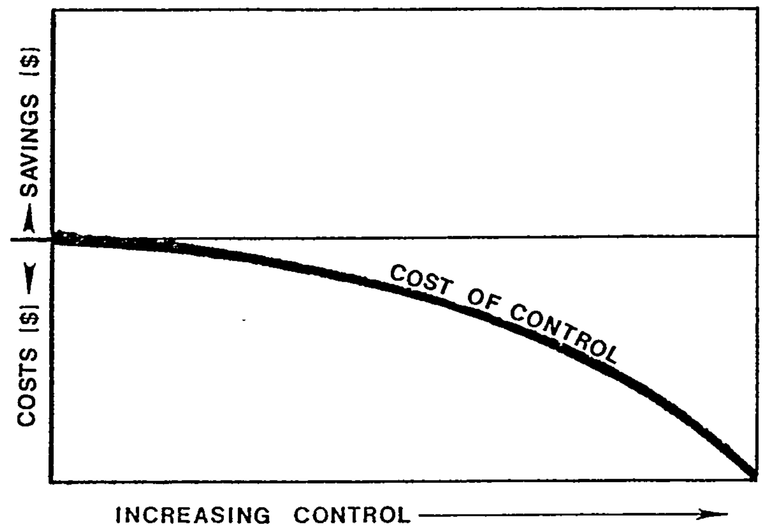

Figure 11B. Cost of Increasing Control

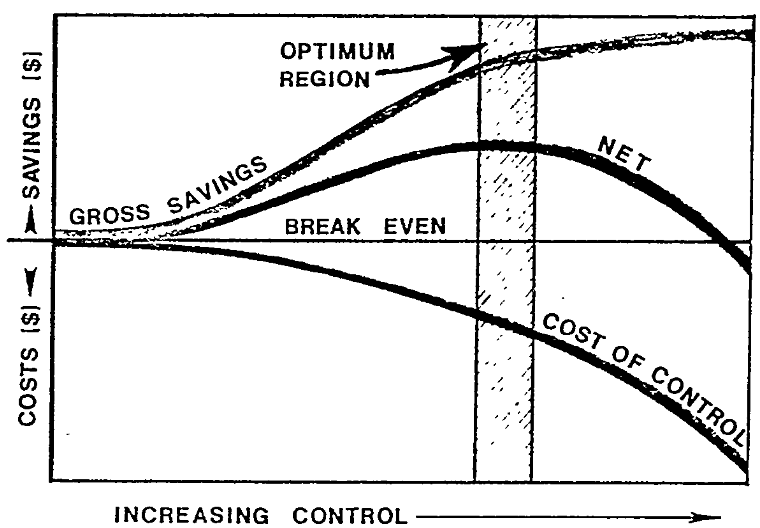

Figure 11C. Cost/Payback From Increasing Control

for control is, then, that level which yields the greatest net savings, namely where the shaded area intercepts the horizontal axis.

ECONOMIC ANALYSIS OF THE INSIDE MACHINE SHOP CONTROL SYSTEM

Returning to the Shop 31 control system problem, deciding whether to increase control to the component level meant determining whether the expected savings from increased control would more than cover the associated costs.

To estimate potential savings, operational audits of work flow in the three shops (inside machine, outside machine and pipe) were conducted. Results of these audits are summarized in Table 1. (The audit team actually found expected savings to be much higher, but to be on the conservative side they scaled their findings down by a factor of two.)

FUNCTION	SAVINGS
MACHINE SHOP INCREASED PERF.	$120
COST REDUCTION CUSTOMER SHOPS	$200
TOTAL ANNUAL SAVINGS	$320

Table 1. Expected Annual Savings from Increased Control ($ in Thousands)

To estimate costs, the study **team** configured two systems to implement controls at the component level within the shop: a completely manual system and a system employing a minicomputer. Functional scope of these two systems was the same. It covered:

- Producing shop work instructions
- Tracking work-in-process
- Collecting labor and material expenditures
- Work station load projection
- Scheduling jobs for level loading work stations.

Control over jobs was, therefore, extended (Figure 12) to cover the complete routing of each job at the work station or machine level.

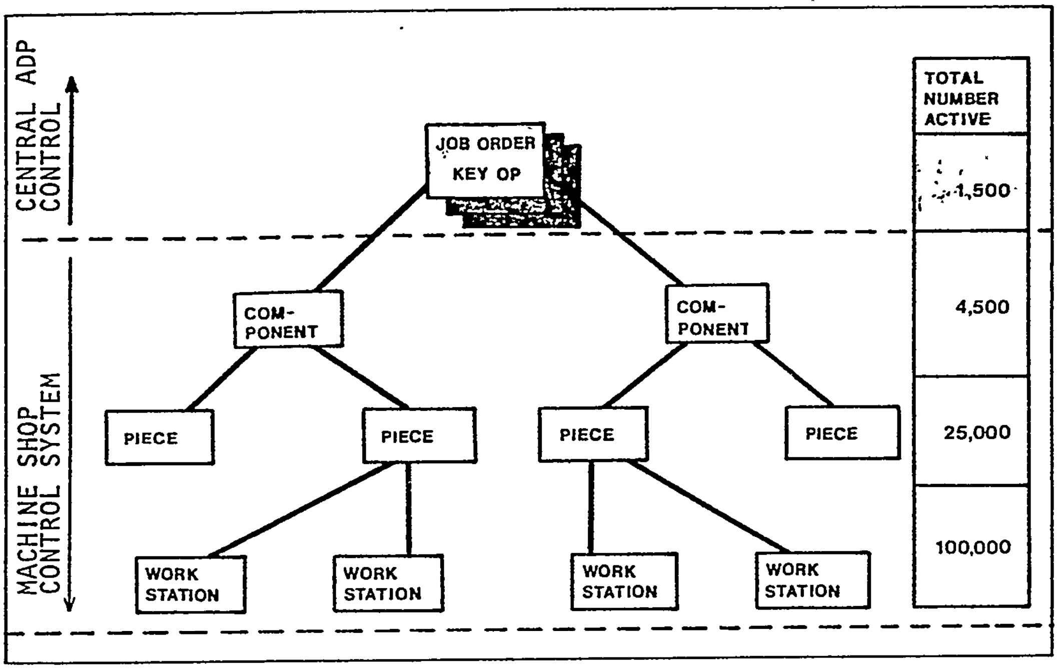

Figure 12. Level of Control for the Inside Machine Shop Control System

The manual system required adding 20 people to the shop planning staff -- each of whom would be responsible for tracking about 200 active jobs. Estimated annual costs of this implementation option are summarized in Table 2.

20 ADDITIONAL PLANNERS	
200 JOBS EACH	
HOURLY WAGES =	$9.00
FRINGE =	33%
COST/MHR =	812.00
COST/MYR =	$24,900
TOTAL ANNUAL COST =	$500,000

Table 2. Cost of the Manual System

With annual costs of about $500 thousand and savings of only $320 thousand, the manual system would lose around $180 thousand per year -- clearly not a desirable situation. If the manual method were the only method available, it would not pay to carry production control to the component level within Shop 31. Shipyard management would have to live with Shop 31 performance analogous to that shown in Figure 7.

FUNCTION	SAVINGS
C.lerical and Expediting	$140
Inside Machine Shop Performance Improvement	120
Pipe/Outside Machine Shop Performance Improvement	200
TOTAL ANNUAL SAVINGS	$460

Table 3. Annual Savings From Minicomputer Option ($ in Thousands)

Investigating the minicomputer implementation option revealed that many routine clerical operations within the shop office could be automated with attendant savings in personnel. Shop planners were spending about 35% of their time physically chasing jobs on the shop floor and searching status records. Thus, in addition to savings from improved inside and outside shop performance, the minicomputer option also captures savings that were not possible with the manual option (Table 3). Estimating the cost of the minicomputer system required the following actions:

- Design of the system
- Preparation of a development plan
- Estimating development costs
- Estimating hardware costs
- Estimating recurring O&M costs

The system was designed to perform the same functions that the manual system did, namely:

(1) Printing shop work instructions

(2) Tracking work-in-process

(3) Collecting labor and material expenditures

(4) Maintaining a library of standardized work instructions

(5) Loading work centers and scheduling jobs

The development schedule covered a period of three years and was divided into three phases. Phase I was to implement items (1), (2) and (3) above; Phase II item (4); and Phase III item (5). The expected costs of system development are shown in Table 4.

		1979	1980	1981
PHASE I	PROGRAMMING	$ 70	$ 20	
	HARDWARE & O & M	80	20	
PHASE II	PROGRAMMING		40	
	HARDWARE		20	
PHASE III	PROGRAMMING			$ 60
	HARDWARE			20
	TOTAL	$ 150	$ 100	$ 80

Table 4. Development Cost of the Minicomputer System

Since the implementation of this system was to take place over a period of three years, the savings estimates had to be factored so that they were properly synchronized with the ex-capabilities of the system, as shown in Table 5.

	PHASE I	PHASE II	PHASE III
CLERICAL & EXPEDITING	$ 90	$140	$140
INSIDE MACHINE SHOP PERFORMANCE IMPROVEMENT	--	*	120
PIPE/OUTSIDE MACHINE PERFORMANCE IMPROVEMENT	200	200	200
TOTAL	$290	$340	$460

*DOES NOT INCLUDE SUBSTANTIAL SAVINGS FROM ENGINEERED LABOR STANDARDS

Table 5. Gross Annual Savings From Shop Control System ($ in Thousands)

The hardware configuration specified for Phase I is shown in Figure 13. There were to be initially six shop floor terminals for the collection of job status, job movement, and labor expenditure data. Four CRT terminals were to be used

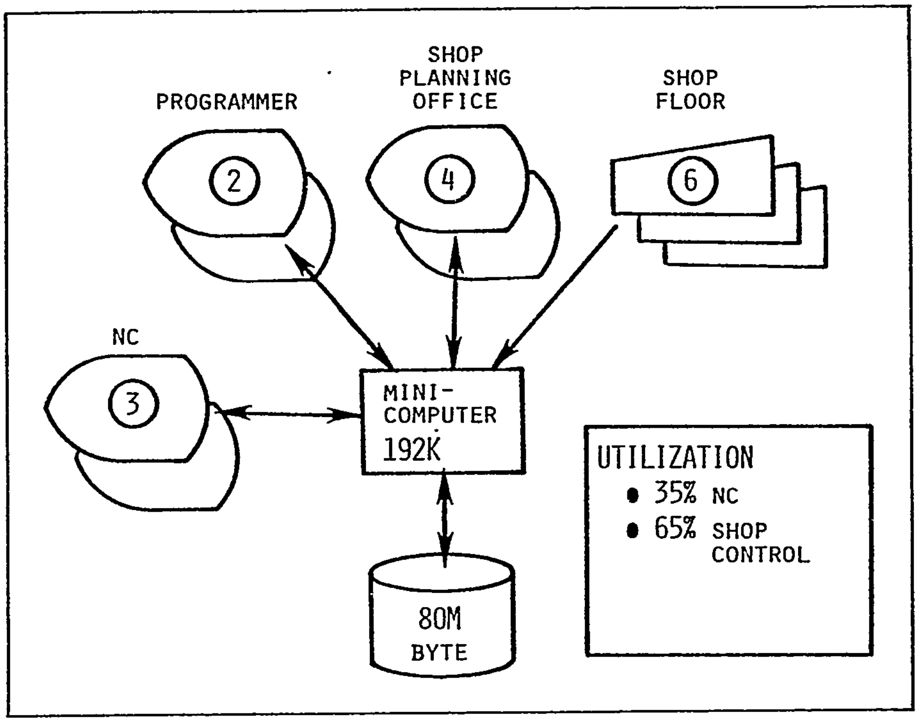

Figure 13. Minicomputer Hardware Configuration

in the shop office for entry of shop work instructions and for on-line inquiry into job status. The other five terminals were to serve NC and programming functions.

It was planned that hardware capacity grow to match phased growth in system capabilities. Additional equipment needs included expanding the memory, adding more disk storage and increasing the number of terminals on the shop floor.

The projection of costs and savings made in **1977** for the minicomputer system is shown in Figure **14.** As can be seen in this figure, projected savings far outweigh development and operating costs; development costs would be fully recovered by the end of three years, and thereafter yield a payback of over $300 thousand a year. The negative slope of the cost curve after completion of system development reflects the fact that the equipment was to be acquired on a lease/purchase arrangement rather than by direct purchase.

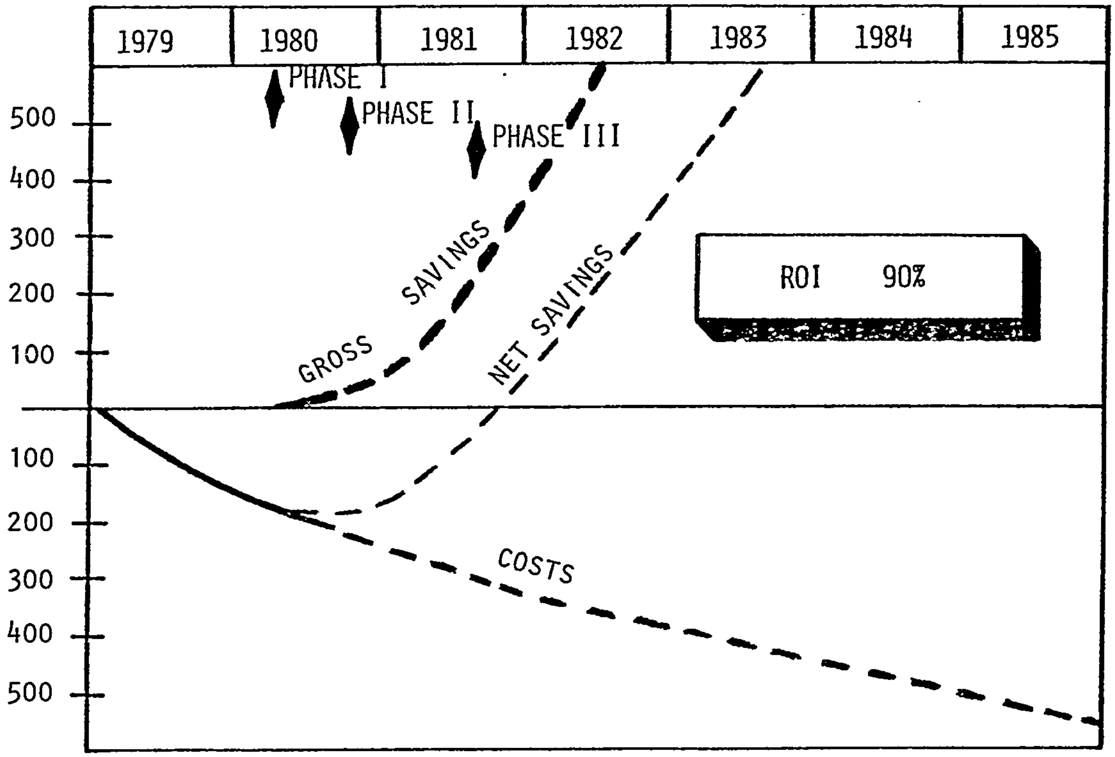

Figure 14. Cost/Payback Curves for Minicomputer System

Return-on-investment for this alternative over the **seven** year period shown was calculated (on the basis of the cost/savings estimates) to be a healthy 90%.

This analysis pretty much demonstrated that control of Shop 31 production operations at the component level was not only economically feasible but promised substantial dollar savings, if it were implemented using minicomputer support. The acquisition of the hardware was therefore approved, and system development actually began in January of **1979.**

EARLY RESULTS

Phase I of the system, which includes issuing shop work instructions and collection of labor expenditure and job status information, was brought on-line in January of 1980. Over the course of the summer all jobs in Shop 31 were brought

on the system, so that it now provides **100%** coverage of all shop work. Manual expediting has virtually ceased; savings projected in **1977** in this area are being realized today. Development costs and the implementation schedule adhered to original plans quite well. In fact, the Phase I programming effort took only one-and-a-half person years.

There are two reasons for this track record. First, there was a dedicated effort to keep the system simple and focused on the fundamental shop problems. Second, and probably more important, development of the, system was accomplished within the shop itself so there was continual interplay between production and data processing people. Each learned to appreciate the other's problems.

Not enough operational data has been collected as yet to measure performance improvements in the outside shops with any degree of confidence. However, the pipe and outside machine shops are even now being given far better component delivery information for scheduling reinstallation and test activities than before. Major improvement should become apparent as soon as procedures are worked out for integrating the component repair and reinstallation schedules of all three shops.

Phase II will be brought on-line this fall and Phase III in about a year. Phase II should see additional improvement in the shop planning area through a reduction in the clerical burden involved in preparing shop work instructions. Incidentally, a combined word processing/data processing system that has been operational in the shipyard central planning office has already demonstrated a 30% reduction in planning costs per overhaul through elmination of many routine clerical functions.

CONCLUSIONS

What do we conclude from this experience?

First, whether it makes sense to use computers in shipyard production control is simply a question of economics, namely, whether the savings from increased control more than cover the cost of the system and provide a reasonable rate of return. Generally speaking, for small shops with fewer than 100-200 active jobs at any given time, a well-thought-out manual system is probably the most cost-effective (Figure 15). Beyond this point automated systems become economically attractive. When the number of jobs exceeds 300 to 400, ADP becomes almost mandatory to exercise close control over productive work and to reap the benefits therefrom.

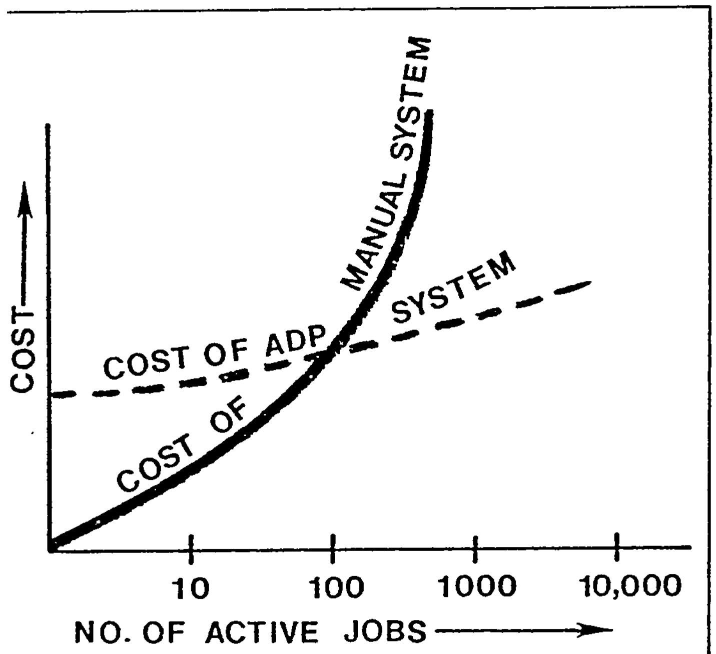

Figure 15. Cost Profiles for Manual and Automated Production Control Systems

Second, automating production control functions by themselves will not guarantee more effective control. The system must be focused on real production needs and must be designed to operate within the shop environment under shop management supervision. Managers must still manage. The system allows managers to identify out of control conditions which require their action.

Third, the dynamics of the waterfront and production shop environment demand an on-line capability for job status tracking

and rescheduling. A centralized batch system is too sluggish to provide any real benefits and usually increases the clerical burden on the shop.

Finally, the system must encompass (Figure 16) all production control functions and operate in a closed-loop mode. If it doesn't, then all of the potential benefits will bleed through the holes.

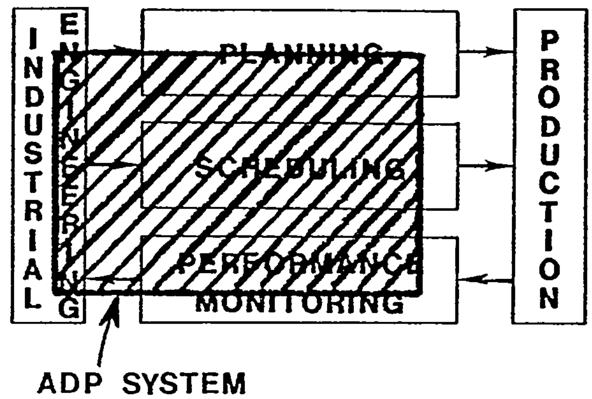

Figure 16. The Proper Place of ADP in Closed-Loop Production Control

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4. Marine Equipment Leasing Co. Inc., Technological Survey of Major U.S. Shipyards, January 1979.

5. Corporate-Tech Planning, Inc., Baseline Performance Data for the Economic Analysis of a Component Tracking System for Inside Machine Shops, February 1977.

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7. Portsmouth Naval Shipyard, Plan of Action for Machine Shop Tracking System, January 1979.

APPLICATION OF MODULAR SOFTWARE TO ESTABLISH A "CLOSED LOOP" SYSTEM FOR SHIPYARD PRODUCTION CONTROL

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ABSTRACT

This paper addresses the key functions of a closed-loop production and inventory, and planning control system generally applicable to the shipbuilding industry. A key feature of the shipbuilding closed-loop system is the application of made-to-order concepts not generally used in production and inventory planning, and control systems for other industries. The use of modular packaged software to make the system operational on a timely step-by-step basis are explored. Special considerations for tailoring the software to satisfy general shipbuilding requirements are reviewed. A summary of the potential benefits of a closed-loop system (i.e., "what if" planning) is also included.

Background

The shipbuilding industry presents challenges to its management that are nearly unequaled in other industries. The dimensions of delivered ships exceed the size of comparable end products. Shipyard engineering must define and control several hundred thousand parts for each design. Much of the equipment used in outfitting ships is advanced state-of-the-art technology. To deliver the ships to budget and schedule, extensive efforts are expended to plan and control the required resources. In most cases, ships are built one-at-a-time and, while not always visible, no two ships of a class/contract are exactly the same. Systems to support shipyard management have generally satisfied single management functions (i.e. master planning, engineering, accounting) and relied on analysts, planners, and expediters to link the functional elements together. In yards with advanced technology shipbuildinq programs (typically associated with a high level of contract specification changes), the efforts required to maintain the functional system links expand quickly.

Despite the intense attention of shipyard management to assure the systems support the various building programs, many situations develop in which material or other resources are not available to satisfy the contract/schedule requirements and schedules/budgets are missed.

Evolution of Closed Loop System

Generally, the complications of planning and controlling shipyard efforts parallels the manufacturing industry with the exception of contract focus, technical specification requirements and traceability. In coping with their system requirements, the manufacturing industry promoted the development of a system concept that became viable as computer applications software technology advanced. Originally, this concept was known as MRP (Material Requirements Planning). With field experience, MRP advocates converted this acronym to mean manufacturing resources planning, since not just material had to be planned and controlled to make production goals. Successful MRP systems captured the imagination of top management and the opportunity to integrate the planning and control process from top to bottom via closed loop concepts (feedback communication and data integration) became reality.

Make-To-Order

Interest on the part of manufacturers who make products for the government led to the refinement of Make To-Order concepts and software which address many of the contract and technical requirements of shipbuilding. The

opportunity now exists to apply 'Closed Loop' concepts in shipyards to support management in planning and controlling resources, priorities, and performance to deliver ships on schedule, at planned costs, at the right ROI, and correctly configured.

Because of the size, complexity, inertia of work-in-process, and overall employee reluctance to change, shipyards cannot expect to install a Closed Loop system overnight. Extensive design, planning, and education efforts are required for all levels of the shipyard organization. A practical approach can be adopted to install the Closed Loop system in modules so shock is minimized and experience builds a strong foundation for success. Overall success of the system will be determined by: 1) constant evaluation and response to the feedback mechanisms and 2) a program to continually monitor key system performance factors.

The following schedules explain in more detail the closed loop system, associated Make-To-Order features, what modular software can be used to build the closed loop system and a strategy for installing the modules:

- Make-To-Order (MTO) Features:
  (Schedule #l)

- Closed loop concept for shipyard production control.
  (Schedule #2)

  - Basic Data
  - Top Management planning
  - Operations management planning
  - Operations execution

- Matrix analysis of shipyard closed loop elements to available software modules.
  (Schedule X3)

- Installation strategy
  (Schedule #4)

SCHEDULE 1
Page 1 of 1

Key features of M-T-O (make-to-order) include:

- Order pegging to control component parts for a given order or contract.

- Allocation of Inventory to specific contracts or orders. (Inventory balances may be optionally maintained by receipt or expiration date, user determined cost, vendor or lot data.)

- Component availability analysis by order or contract.

- Mass rescheduling or order cancellation by order or contract.

- Tracking of material issues by order or contract for actual cost purposes (issues from stock in optional data sequence, such as FIFO).

- Maintain bill-of-material user comments for special purposes such as additional engineering change revision information.

- Material lot control through reference identification on inventory transactions by order or contract.

- Order or contract configuration history by reporting the pegged structure, component revision level and actual quantities for closed orders.

"CLOSED LOOP" CONCEPT FOR SHIPYARD PRODUCTION CONTROL

BASIC DATA

BASIC ELEMENTS	FUNCTION	INPUT TO
BILLS OF MATERIAL DATA	Maintain part specifications Define each product on level **by level basis -** for **all** functions Maintain product configuration (Hull effectivity)	. Construction Planning/Master Scheduling . Key Event/System Scheduling . Requirements Planning . Inventory Planning . Product Costing . Product Design . CAD/CAM
INVENTORY DATA	Maintain inventory balances and order **status** data **by** part and contract	. Requirements Planning . Inventory Control . Purchasing . Performance Accounting . CAD/CAM
ROUTINGS	Maintain specifications for manufacturing process of a part	. Construction Planning . Master Scheduling . Shop Floor Control . CAD/CAM . Product Costing . Performance Accounting

"CLOSED LOOP" **CONCEPT** FOR SHIPYAIRD **PRODUCTION CONTROL**

TOP MANAGEMENT PLANNING

Closed Loop Element	Function	Input to	Feedback
BUSINESS PLANNING - Objectives -	Set overall objectives of company and manage to support those objectives	Production Planning Sales Planning	Bottom line
SALES PLANNING	Plans sales to **meet** objectives	Production Planning	Market Success
PRODUCTION PLANNING - Resources -	Determine rates and allocate the resources required to meet the company's business objectives and satisfy contract/construction demands.	Mdster Scheduling . what to schedule . Schedule Adjustments Inventory Plan	Business Planning **.Evaluate and adjust** the plan
MASTER SCHEDULING - Product -	States production demands in terms of "what", "How **Much"** and "When". Provides **key** facility **load** analysis (Rough **cut** capacity plan). Interface with **master construction/key event/** system schedules.	Materials Requirements Planning . What . How much . When	Production Planning . Realism . Adjust the plan . Adjust the resourses

:OI :P) ODUC'

RA ME NNING

Closed Loop Element	Function	Input to	Feedback
MATERIAL REQUIREMENTS PLANNING - Priority -	Calculates requirements, plans orders and maintains priorities (time phased) using master schedule, bills of material and inventory status.	Inventory Control . Detail Requirements . Planned orders	Master Scheduling . Master Schedule Input
INVENTORY CONTROL - Availability - - Contract Operations Management -	VANILLA Maintains part balance and order status data MTO Explodes order requirements at all levels to support construction schedules Maintains contract and common stock part balance and pegged contract order status Maintains lot control/contract location Maintains contract allocations Drives contract accounting	Capacity Requirements Planning . Detail Order Data for Load Analysis Purchasing .Purchasing Requirements Performance Accounting . Planned/Actual Data	Production Planning . Inventory Status Master Scheduling . Inventory Status . Relieves Master Schedule Material Requirements Planning . Covered Requirements
CAPACITY REQUIREMENTS PLANNING -Ship/Shop/Floor Capacity-	Assists in determination of the most efficient production schedule based on projected facility load.	Production Planning . Load analysis Master Scheduling . Load analysis	Operations Execution Function . Detail Planning for resource check

"CLOSED LOOP" CONCEPT FOR SHIPYARD PRODUCTION CONTROL

OPERATIONS EXECUTION

Closed Loop Element	Function	Input to	Feedback
SHOP FLOOR CONTROL - Schedule Performance -	Executes the plan by controlling Ship/Shop capacity and priorities, reporting contract order status and maintaining delivery, quality and productivity performance.	Performance Accounting	Adjustments for: Master Scheduling Material Requirements Planning Inventory Control Capacity Planning
PURCHASING - Schedule Performance -	Executes the plan by controlling vendor capacity and priorities, reporting purchase order status and maintaining delivery, quality and and cost performance.	Performance Accounting	Adjustments **Master Scheduling** Material Requirements Planning Inventory Control Capacity Planning
PERFORMANCE ACCOUNTING (Cost and Inventory Accounting) - Accountability - - Progress - - Cost at Complete -	Status, maintains and reports key cost, rate and other variance data. Drives progress accounting and cost at complete analysis	All	Master Scheduling Material Requirements Planning Inventory Control Capacity Planning Bill of Material (Design Engineering) Routing data Overall Business Planning

MATRIX ANALYSIS OF SHIPYARD CLOSED LOOP ELEMENTS

TO AVAILABLE SOFTWARE MODULES

CLOSED LOOP ELEMENT	GENERALLY APPLICABLE MODULE	SYSTEM INSTALLATION CONSIDERATIONS
BUSINESS PLANNING	MODELING SYSTEM	NO CHANGES EXPECTED BUT MUST CONTAIN STRATEGIES AND INTEGRATE TO PRODUCTION PLAN
PRODUCTION PLANNING (Contract/Construction Planning)	COST SCHEDULE CONTROL SYSTEM Generally home grown but packages are available	KEY EVENT/SYSTEM SCHEDULING WORK BREAKDOWN STRUCTURE ACTUAL COST AND PROGRESS DATA INTERFACE SCHEDULE MAINTENANCE EXPLOSION/ CAPABILITY

CLOSED LOOP ELEMENTS TO SOFTWARE MODULES

CLOSED LOOP ELEMENT	GENERALLY APPLICABLE MODULE	SYSTEM INSTALLATION CONSIDERATIONS
MASTER SCHEDULING	MASTER SCHEDULING	TECHNIQUE TO INTERFACE WITH PRODUCTION PLANNING (WORK PACKAGE) CONTROL SYSTEM HOW TO MAINTAIN PLANNING BILLS FOR LONG LEAD MATERIAL HOW TO PLAN/FORECAST SERVICE REQUIREMENTS - SHOPS - MOLDS, SPECIAL EQUIPMENT, JIGS, FIXTURES - SPARES - OTHER PRODUCTS ROUGH CUT LOAD ANALYSIS LEVEL FOR LABOR/MACHINE/FACILITY HOW TO FORMALLY KEEP OFF HULL WORK PACED TO ON HULL WORK (TIME FENCES) - POLICIES MUST BE STRICT TO MAINTAIN MOMENTUM BUT PRACTICAL TO GET MAXIMUM FROM EQUIPMENT, MANPOWER AND MATERIAL

CLOSED LOOP ELEMENTS TO SOFTWARE MODULES

CLOSED LOOP ELEMENT	GENERALLY APPLICABLE MODULE	SYSTEM INSTALLATION CONSIDERATIONS
BILLS OF MATERIAL PART SPECIFICATION	DESIGN ENGINEERING	HULL EFFECTIVITY?. PLANNING/BID BILLS CONTRACT CHANGES WORK BREAKDOWN STRUCTURE ORDER/WORK PACKAGE CONCEPTS INTERFACES TO CAD/CAM PART SPECIFICATION
INVENTORY DATA AND INVENTORY CONTROL	INVENTORY CONTROL (MTO CAPABILITIES)	ORDER PEGGING AND RELATED NETWORK REQUIREMENTS (MTO Requirements) ORDER LAUNCH AND CONTROL LOT CONTROL/TRACEABILITY CONTRACT ALLOCATIONS INTERFACES TO CAD/CAM STOP WORK NOTIFICATION AND CONTROLS CLOSE OUT MECHANISM

CLOSED LOOP ELEMENTS TO SOFTWARE MODULES

CLOSED LOOP ELEMENT	GENERALLY APPLICABLE MODULE	SYSTEM INSTALLATION CONSIDERATIONS
ROUTINGS	MANUFACTURING ENGINEERING	INTERFACES TO GROUP TECHNOLOGY? HULL APPLICABILITY? QUALITY REQUIREMENTS
MATERIAL REQUIREMENTS	MATERIAL REQUIREMENTS PLANNING	ALLOCATE TO CONTRACTS AND DETERMINE NET REQUIREMENTS BY CONTRACT MTO/RP INTERFACE
CAPACITY REQUIREMENTS PLANNING	CAPACITY PLANNING	NONE SPECIAL AT INDUSTRY LEVEL
SHOP FLOOR CONTROL	SHOP FLOOR CONTROL	NONE SPECIAL AT INDUSTRY LEVEL
PURCHASING	PURCHASING	GENERALLY HOME GROWN SHOULD ADDRESS BID PROCESS, VENDOR QUALIFICATIONS AND RELIABILITY, AND SPECIAL REPORTING

CLOSED LOOP ELEMENTS TO SOFTWARE MODULES

CLOSED LOOP ELEMENT	GENERALLY APPLICABLE MODULE	SYSTEM INSTALLATION CONSIDERATIONS
PERFORMANCE ACCOUNTING	INVENTORY ACCOUNTING	HOW TO MAINTAIN "BID BILL" BY CONTRACT AND MEASURE - ENGINEERING TAKEOFF VARIANCES - ACTUAL USAGE VARIANCES INTEGRATION WITH CONTRACT CHANGE - FOLLOWUP COST ANAYSIS CONTRACT ACCOUNTING
	PRODUCTION COSTING	USING THE VARIANCES IN MANUFACTURING TO EVALUATE BID/ESTIMATES - ESTIMATE - BID - PURCHASING - MATERIAL - MANUFACTURING (Labor) MAINTAIN FULL ABSORBTION OF COST IN PRICED OUT BILLS - UNIT COST EFFECTIVITY?

CLOSED LOOP SYSTEM FOR SHIPYARD PRODUCTION PLANNING AND CONTROL

INSTALLATION STRATEGY

Step	Modules Addressed	Benefits Anticipated
1	Design Engineering Manufacturing Engineering	Accurate and timely product engineering information - Bills and routings - Product specification control Hull effective engineering change tracking and control Work package preparation, dispatch and control
	Manufacturing Engineering	Minimize manufacturing lead times and related costs by facility usage control
2	Inventory Control/Make To Order	Accurate part balance/contract order status Contract order network control Work packages generation and control Visability of order/construction status Support schedule definition Contract material location control Historical data maintenance by contract Long lead item control Improved contract change evaluation and control capabilities
3	Master Scheduling Material Requirements Planning	Rough cut validation of construction plan Order planning Control of common manufactured parts Interface with MIO for full BOM control
4	Shop Floor Control	Coordination of schedules at lower level Improved shop scneduling for addressing alternative manufacturing strategies Detail status of manufacturing work - Permits input/output control Ship/Shop - QC/NQC interface
5	Capacity Planning	Efficient facility loading Minimize production delays
6	Inventory accounting (Product costing	Variance analysis for improved bids and contract Change support Effective support of progressing and CAC analysis Integrated contract accounting Ties performance to business planning Closes the loop

APPLICATION OF MODULAR SOFTWARE TO ESTABLISH A "CLOSED LOOP" SYSTEM FOR SHIPYARD PRODUCTION CONTROL

SHIPBUILDING ENVIRONMENT

- LEADERS IN ADVANCED TECHNOLOGY PROCESSES
- ENVIRONMENTAL AND SAFETY FACTORS EMPHASIZED
- MORE OFF HULL WORK
- VERTICAL INTEGRATION EXPANDING
  - MORE OPPORTUNITIES FOR PROFIT
  - TOLERANCES DIFFICULT TO MEET
  - HIGH LEVEL OF EXPEDITING
- COMPETITIVENESS
- MAKE-TO-ORDER FOCUS

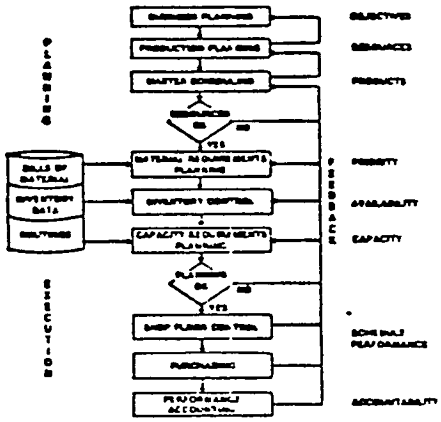
IN A SHIPYARD, WHAT IS A CLOSED LOOP SYSTEM?

IT IS AN INFORMATION SYSTEM FOR PLANNING AND CONTROLLING RESOURCES, PRIORITIES, AND PERFORMANCE TO DELIVER SHIPS.

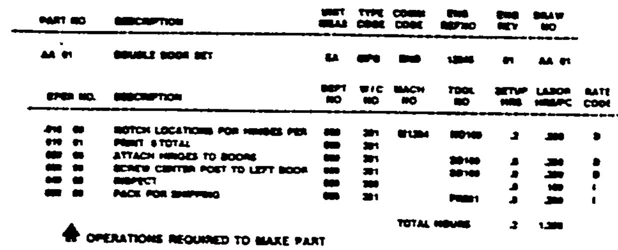
- ON SCHEDULE
- AT PLANNED COST
- AT THE RIGHT ROI
- CORRECTLY CONFIGURED

SHIPYARD PLANNING AND CONTROL

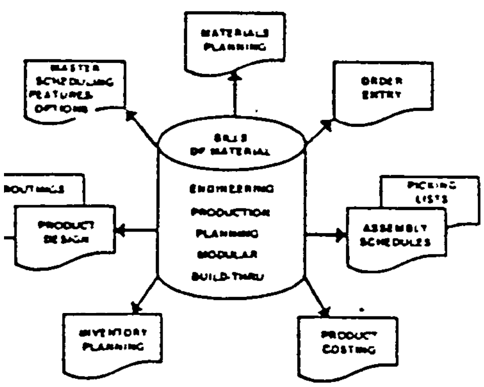
CLOSED LOOP MANUFACTURING SYSTEM



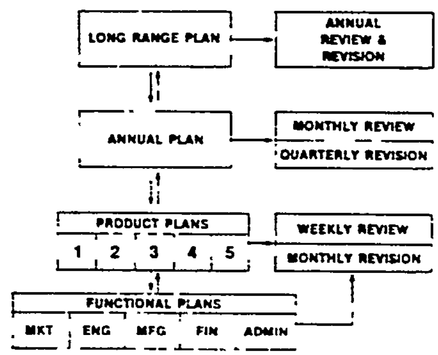
MASTER ROUTING



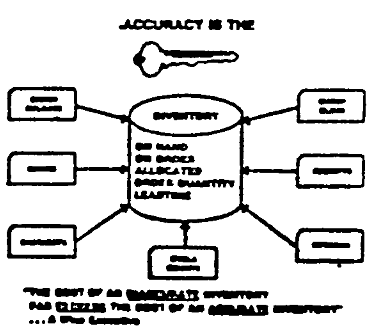
BILL OF MATERIAL USES



BUSINESS PLANNING CYCLE



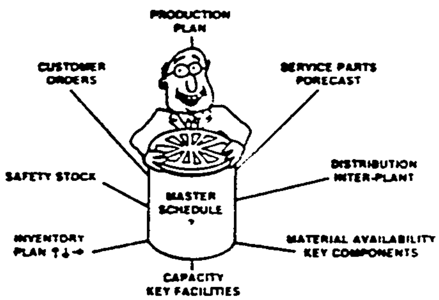
INVENTORY TRANSACTION CONTROL



PRODUCTION PLANNING OVERVIEW

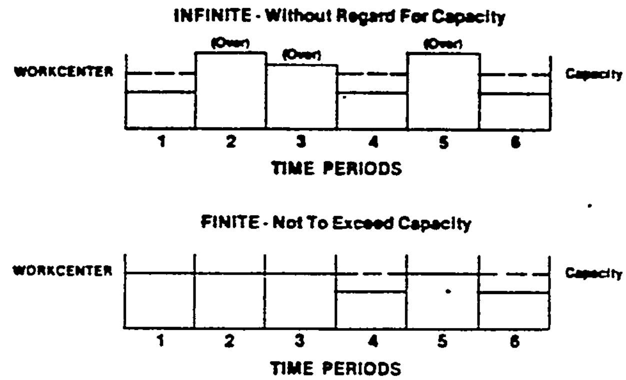
ALLOCATE COMPANY RESOURCES TO CAPITALIZE ON THE "BEST" MARKETPLACE OPPORTUNITIES

MASTER SCHEDULE INPUT

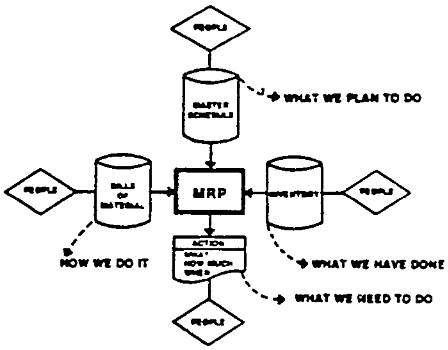


IS MASTER SCHEDULING A BIG JOB? YES!
IT IS THE DRIVER FOR MRP

LOADING METHODS

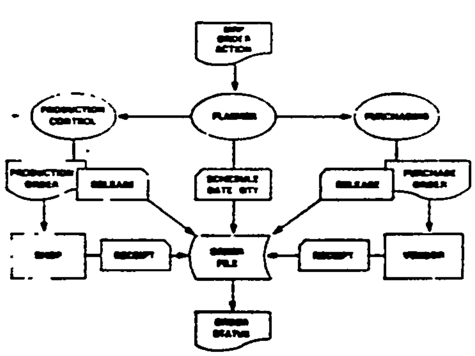


MRP SYSTEM OVERVIEW



"A PLAN THAT EXCEEDS CAPACITY WILL NOT GET PRODUCED AND WILL BUILD INVENTORY"

PRODUCTION & PURCHASE ORDER CONTROL



PRIORITY DISPATCH LIST — DATE [illegible]

WORK CENTER	PART NO	ORDER NO	OPER NO	QUANTITY ORDER	QUANTITY COMPLETE	QUANTITY BALANCE	HOURS	SCHEDULE START	SCHEDULE DUE
102	*AA02	12333	010	10	0	10	5	6-27-X	6-27 X
	AA10	12444	020	25	0	25	5	6-30-X	6-30-X
	*AA01	12345	020	100	50	50	50	7-01-X	7-07 X

WORKCENTER/START DATE SEQUENCE

*AVAILABLE AT WORK CENTER

SHIPYARD PLANNING AND CONTROL

INPUT-OUTPUT CONTROL

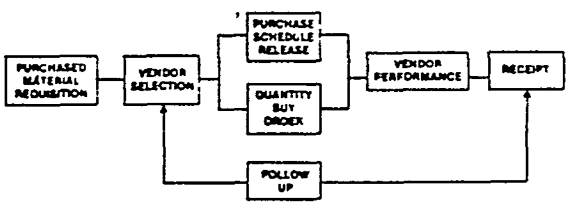
			WEEK			
			1	2	3	4
INPUT CRP	PLANNED		260	260	260	260
	ACTUAL		260	255	260	
	CUMM DEVIATION		0	−5	−5	
OUTPUT SFC	PLANNED		290	290	290	290
	ACTUAL		295	250	270	
	CUMM DEVIATION		+5	−35	−55	
BACKLOG STATUS	PLAN	300	270	240	210	180
	ACTUAL		265	270	260	

"A PLAN THAT EXCEEDS CAPACITY WILL NOT GET PRODUCED"

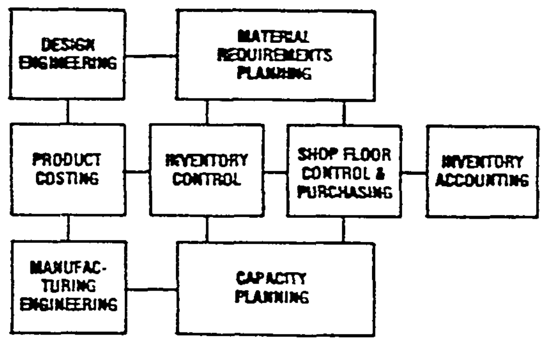
PERFORMANCE MEASUREMENT

PERFORMANCE AREA		RESPONSIBILITY
BILL OF MATERIAL		ENGINEERING
PERFORMANCE CRITERIA	PERFORMANCE MEASUREMENT	MEASUREMENT METHOD
PRODUCT STRUCTURE	PARTS, QUANTITIES, LEVEL BY LEVEL FOR ASSEMBLY	PULL PARTS AND ASSEMBLE
ENGINEERING CHANGE CONTROL	PLANNED AND ACTUAL EFFECTIVITY DATES	WEEKLY BOM EFFECTIVITY STATUS REPORT
OBSOLETE INVENTORY	OBSOLETE INVENTORY NMT 5% OF TOTAL INVENTORY	QUARTERLY OBSOLETE INVENTORY ANALYSIS REPORT

PURCHASING FLOW



MAC-PAC
MANUFACTURING PLANNING AND CONTROL SYSTEM



PERFORMANCE QUESTIONS

- WHAT IS THE PERFORMANCE?
- WHAT SHOULD IT BE?
- WHAT IS PERFORMING?
- WHAT IS NOT?
- WHAT ACTION IS REQUIRED?
- WHO IS RESPONSIBLE?
- WHEN WILL IT BE DONE?
- WHAT IS THE FOLLOW-UP?

CLASS A, B, C, D USERS

SYSTEM CLASSIFICATION	SYSTEM PERFORMANCE	SYSTEM CHARACTERISTICS
A	95%	COMPLETE CLOSED LOOP SYSTEM. TOP MANAGEMENT USES THE FORMAL SYSTEM TO RUN THE BUSINESS. ALL ELEMENTS AVERAGE [illegible] TO [illegible].
B	85%	FORMAL SYSTEM IN PLACE BUT ALL ELEMENTS ARE NOT WORKING EFFECTIVELY. TOP MANAGEMENT APPROVES BUT DOES NOT PARTICIPATE. ELEMENTS AVERAGE [illegible] TO [illegible].
C	70%	MRP IS ORDER LAUNCHING RATHER THAN PLANNING PRIORITIES. FORMAL AND INFORMAL SYSTEM ELEMENTS ARE NOT TIED TOGETHER. SOME SUB-SYSTEMS NOT IN PLACE. ELEMENTS AVERAGE [illegible] TO [illegible].
D	50%	FORMAL SYSTEM NOT WORKING, OR NOT IN PLACE. POOR DATA INTEGRITY. LITTLE MANAGEMENT INVOLVEMENT. LITTLE USER CONFIDENCE IN SYSTEM. ELEMENTS ARE [illegible] OR BELOW.

PHOTOGRAMMETRIC THREE-DIMENSIONAL DIGITIZING OF PIPING ARRANGEMENT SCALE MODELS FOR COMPUTER INPUT

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Mr. Kenefick was instrumental in forming the Photogrammetric Services Division of DBA Systems Inc, and served as director of the division for 4 years prior to establishing his own firm. Over 40 technical reports dealing primarily with analytical photogrammetry have been authored or coauthored by Mr. Kenefick.

He holds degrees in civil engineering and geodetic science from the Ohio State University.

ABSTRACT

In July 1976 MarAd, in cooperation with Todd Shipyards Corporation, Seattle Division, published a National Shipbuilding Research Program report entitled "Photogrammetry in Shipbuilding". Efforts put forth in the conduct of that project represented the U.S. shipbuilding industry's first exposure to photogrammetry, the science of obtaining two- and three-dimensional measurements from photographs. Included within that report were detailed descriptions of four surveys conducted under real shipyard conditions. One of these employed photogrammetry to produce a composite drawing of a ship's machinery space using photographs of its design mode. This initial work allowed MarAd to develop the foresight that digital photogrammetry could be an ideal means by which the geometry of distributive systems , as portrayed on inherently interference-free design models, could be put directly into a computer and "married" to already developed automated detailing systems.

In the followon project described herein, photogrammetric procedures and basic computer programs were developed which would allow piping geometry and events to be expressed in terms of coordinates in a ship's coordinate system; i.e., in precisely the same form that input to computerized pipe detailing systems must be presented. The fact that piping geometry can be "lifted" photogrammetrically from a design model is not so striking until one considers the alternative methods. Only then does the practicality of photogrammetry become clear. Without extreme measures, pipe lengths and in-line locations of pipe events can be determined with a typical accuracy of + ½ inch or better, onboard from photographs of a 1:15 design model.

The excerpts contained herein are from a forthcoming publication by Todd Pacific Shipyards Corporation, Seattle Division, in cooperation with the Maritime Administration for the National Shipbuilding Research Program.

Design models (or engineering models) are inherently interference-free and are built' by designers who work directly from system diagrammatics. They do not first prepare costly and time consuming system- and composite-arrangement drawings. Thus, shipbuilders in Europe and Japan are striving by different means to perfect cost-effective methods for obtaining the following directly from design models:

- o pipe-piece details,
- o material lists, and
- 0 assembly instructions.

The subject research discloses that marrying three existing disciplines, each already proven in industry, achieves the desired objectives; see Figure 1-3 attached.

The other excerpts contained herein are Chapter 2 - Concjusions and Appendix E - Details of the Developed Photogrammetric System.

L.D. Chirillo
R&D.Program Manager &
Chairman, SNAME Panel SP-2

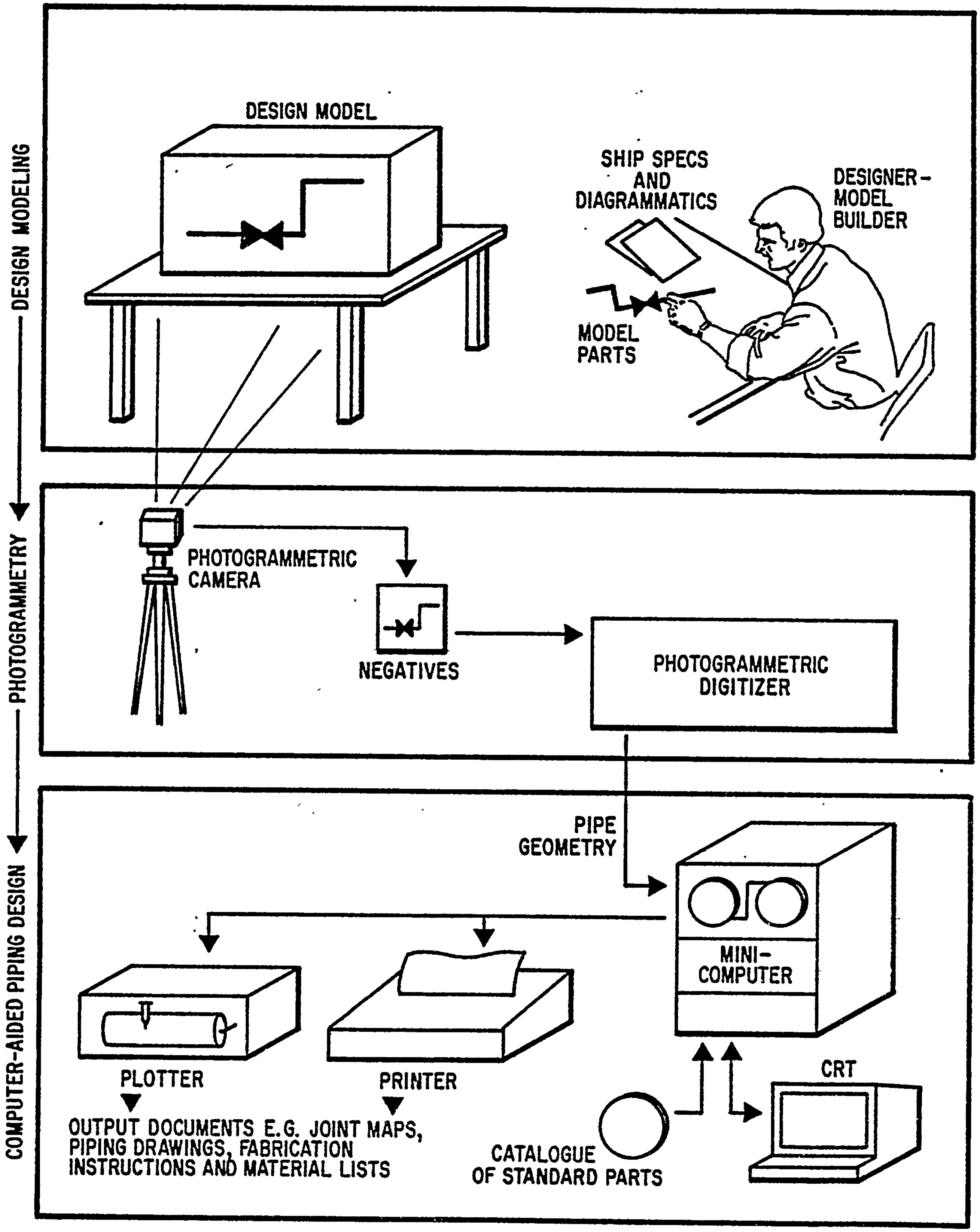


FIGURE 1.3 : The Marriage of Design Modeling, Photogrammetry and Computer-Aided Pipe Detailing Systems.

2. CONCLUSIONS

Photogrammetry does provide a productive means by which dimensions may be "lifted" from design models. The practical application of photogrammetry relies to a large extent upon processes peripheral to photogrammetry per se. Hence, it is appropriate to identify all related functions and to state conclusions with respect to each.

2.1 Model Building Technique

Distributive systems of a model can be productively dimensioned by photogrammetry only if forethought is given to the manner in which the model is constructed and presented.

2.1.1 Model Sectioning

To facilitate "photographic access" to the interior of a model, the model must be built on multiple model bases. Divisions atmidships, bulkheads and decks are desirable, although any other divisoning scheme such as along outfitting blocks is suitable. Sub-divisioning so that overheads can be removed and photographed separately is also a requirement. See also paragraph 2.1.3.

2.1.2 Minimal Use of Plexiglass

To minimize geometric distortions and reflections which occur on photographs "viewed". through plexiglass,. the amount of plexiglass used must be held to a minimum. Where plexiglass must be used, cutouts should be employed to the greatest possible extent. See also paragraph 2.1.3.

2.1.3 Removable Components

Wherever it is practical, machinery components and platforms should be removable. This also permits the distributive systems to be photographed with fewer obstructions and/or distortions and reflections.

2.1.4 Color Coding

Color coding of the various distributive systems is essential to any photographic documentation program. Color coding is particularly beneficial to photogrammetric work because black and white photographs may be employed. These are readily interpreted owing to tonal differences rendered by the color coded distributive systems.

2.1.5 Finishes

Surface finishes of structural, machinery and distributive system components should not be highly reflective. Dull finishes are preferred because they reflect light in a diffuse manner, thereby reducing "glare" on the photographs.

2.1.6 Tags

Tags placed on machinery pieces and distributive systems are sometimes helpful when interpreting photographs. However, they should not be so bulky as to obscure portions of distributive systems. In particular, tags on pipes must be completely adhered to the pipes. Bulky tags attached tangent to pipes oftentimes obscure edges of the pipes.

2.1.7 Representation of Piping

Because procedures developed for photogrammetric dimensioning of distributive systems models are quite general, piping may be represented in the model true-to-scale or by the centerline method. For photogrammetric purposes the centerline presentation is the most desirable because it presents the least interference with photographic viewing into the model. Trends in modeling technique indicate, however, that the centerline method of portrayal is not likely to be used with frequency.

2.2 Photography

2.2.1 Preparation of the Model

Model sections require very little preparation in advance of taking the photographs. Preferably, a few points of known (or partially known) ship's coordinates are fit with small adhesive bull's-eye targets to permit accurate identification later on in the digitizing work. It is also desirable to place a few additional targets at dispersed, easily viewed yet arbitrary locations. These permit accurate matching of different photographic views of the same model section (see paragraph 2.2.2).

2.2.2 Procedures

The photographic process should not require that the model be brought to a photographic laboratory. Instead, the camera(s) should be taken to wherever the model may be situated. Procedures for setting up the model and for taking the pictures should be so simple that they can be readily implemented without elaborate preparation.[1] This includes positioning of the camera and lighting.

Stereophotography of model sections is required so that the photographs can be viewed in a stereodigitizer. The camera may be mounted upon a tripod or it may be hand-held. The base-distance ratio, i.e. the distance between camera positions relative to the distance from the camera locations to the object, must be small. Wide separations between cameras cannot be employed because stereoscopic coverage of vertical pipes is lost owing to their cylindrical shapes.

[1]Such a scheme is described in Appendix E.

Pairs of stereophotographs must be taken from widely different vantage points. This virtually eliminates chances for "lost detail". That is, piping detail which may be obscured on one pair of photographs will likely be visible on some other pair taken from a different vantage point.

It is also desirable to take the stereophotographs such that the camera ares are inclined relative to the model section. This also facilitates viewing detail which might otherwise be obscured if, for example, the camera axes were in or near a plane containing a number of horizontal pipe runs.

Lighting-is best provided by electronic strobes aimed away from the model to nearby walls and the ceiling. This produces uniform "bounce" lighting of the model which minimizes "glare" and shadows on the photographs.

Ordinary black and white panchromatic emulsion is entirely suitable for photogrammetric work. However, color snapshots should also be taken for reference when there is an occasional need for aid in interpreting the black and white photographs.

2.2.3 Hardware

A single, variable focus photogrammetric camera is best suited to model photography. This type of camera (as opposed to a fixed focus double camera) provides far greater flexibility for accommodating varying sizes of model sections. It is also more portable and easier to handle while taking pictures. The same type camera is also well suited to other shipyard tasks such as dimensioning large steel units.

Electronic strobes are needed to provide artificial lighting of the model. Because bounce lighting is preferred and also

because the camera may be hand-held, the combined output of the strobes must be much greater than would ordinarily be required for other types of photographic work. A combined total output capability of at least 1,200 watt-seconds in a single flash is desirable.

2.3 Preparation for Stereodigitizing

It is felt that the operator of the stereodigitizer should not be burdened with non-photogrammetric selection and decision making functions, lest his productivity on the digitizer be drastically reduced. Two pre-digitizing preparations serve the purpose of maximizing productivity at the digitizing stage.

2.3.1 Photo Enlargements

Occasionally, for personal orientation, the operator of the stereodigitizer needs to refer to an overall view of the model. A black and white enlargement of one of the two photographs set in the stereodigitizer serves this purpose. Such enlargements also serve as a medium on which detail to be digitized can be annotated.

2.3.2 Transparent Overlays

Detail to be digitized is preferably annotated on transparent overlay(s) of the photographic enlargement instead of on the enlargement itself. This procedure leaves the enlargement in its original form to serve its first intended purpose (paragraph 2.3.1). It is also possible to use more than one overlay if a single overlay should become too cluttered or if it is desired to separate types of detail to be digitized.

2.3.3 Precomputed Stereodigitizer Settings

Of two basic types of stereodigitizers that can be used for dimensioning design models (paragraph 2.4.1), one requires manual orientation of one photograph of a stereopair to the other. This is a difficult time-consuming process, even for an experienced photogrammetrist. It is state-of-the-art, however, to analytically calculate dial settings for any stereopair in advance of presenting the photographs to the stereodigitizer. This requires measurement of images of corresponding points on each photograph (usually on a monocomparator). These measurements are then computer-processed to produce stereodigitizer settings which may be dialed into the instrument as an initial step before stereodigitizing of *a* stereopair commences. Although this process of precalculating settings is theoretically unnecessary, it is required as a practical matter for productivity reasons.

2.4 Stereodigitizing

2.4.1 Hardware

Two types of photogrammetric instruments are suited to the task of dimensioning from models. The first is an analogue stereoplotter. However, only analogue stereoplotters having the following attributes may be employed:

- accommodation of a wide range of focal lengths
- large height range
- short camera separation capability

[1]Analogue stereoplotters are intended primarily for topographic mapping from aerial photographs. But, some have liberal mechanical ranges which render them suitable for some non-topographic tasks.

- digital output in all three axes

A computer-controlled stereoplotter may also be employed. Relative to the analogue instrument its major advantages are:

- by virtue of the computer-aided stereoscopic viewing, there are no practical limitations that are otherwise imposed by mechanical functions of analogue stereoplotters, thus permitting greater freedom in the picture taking process since there is no longer a concern for exceeding mechanical limitations of an analogue instrument.

- precalculation of instrument settings (paragraph 2.3.3) is not necessary since the on-line computer handles this task

2.4.2 Procedures

It was found that having designed a general dimensioning scheme, such as outlined in Appendix E, stereodigitizing procedures are very simple. It is not necessary to follow a complicated hierarchical system in order ***to*** gather data needed to ultimately construct the paths of pipe runs and locations of in-line events (see paragraph 1.5). But, it does serve to avoid confusion and omissions of data if pipe runs and pipe events are separately digitized. Such separation does not imply, however, separate setups of the stereodigitizer.

The digitizing scheme developed for this project required that random points on the surface of each straight-line pipe segment be digitized. Once all pipe segments within a given stereomodel were digitized, one or two points on each pipe event were digitized. All such data were later processed through a series of computer programs to arrive at the desired end products: coordinates defining the paths of the pipe centerlines and coordinates fixing the centerline locations of pipe events.

2.5 Data Processing

Data processing steps and computational algorithms depend almost entirely upon how the preparation and stereodigitizing efforts are designed. The scheme developed for this project is describing in detail in Appendix E. This particular procedure dictated that the computational flow proceed in the following sequence:

- conversion of digitized coordinates to ship's coordinates
- **sorting data belonging to identical features but** digitized in different stereomodels
- calculation of *a* centerline for each pipe *segment* by fitting a cylinder to digitized points on *the* pipe surface
- calculation of coordinates of bend intersection points by intersecting computed centerlines of adjacent pipe segments
- calculation of centerline locations of each pipe event by projecting a line through a digitized point on the event, perpendicular to the previously computed centerline of the corresponding pipe segment.

2.6 Evaluation of End Results

2.6.1 Accuracy

By virtue of having computed coordinates of bend intersection points it is a simple matter to calculate the space distance between adjacent bend intersections. Such calculated distances were compared to corresponding distances as physically scaled on the model. Over all distances compared the average difference was 8.4 mm (0.33 inch) and the maximum difference was 40.0 mm (1.57 inch) on board.

A similar scheme was employed to check computed locations of pipe events; i.e. their locations distance-wise from the nearest bend intersection. The average difference was 12.6 mm (0.50 inch) with a maximum of 28.0 mm (1.10 inch).

It was further concluded that the photogrammetric results were far more reliable than physical measurements of the model. Initial comparisons of pipe lengths and locations of pipe events revealed an extraordinary number of blunders in the physical measurements. These blunders almost always resulted from the inability to directly measure a scale model by hand. Although this is partly due to congestion of model detail, the principal imposing factor is that it is not possible to take measurements directly to pipe or event centerlines. Instead, one is constantly faced with taking alternate distances and then modifying these to account for offsets, pipe radius, etc. Perhaps the greatest detraction of all is the inability to physically find bend intersection points, particularly for other than 90-degree bends. Hence, accuracy figures given above are likely to be pessimistic.

2.6.2 Completeness

If a general digitizing scheme such as the one described in Appendix E is employed, virtually all piping detail can be extracted from the model. This is partly because digitizing is performed within stereo pairs of photographs taken from several different vantage points. This serves to minimize data loss caused by obscurations within the model which often occur if only photographs from one vantage point are used. Secondarily, because it is necessary only to digitize random points ***on*** a pipe's surface (and later fit a cylinder to these points), it is necessary only to be able to see portions of a pipe's surface in any given stereo pair. Also see paragraph 2.2.2.

2.6.3 Cost

Paragraph E.3.1 describes and illustrates the Hitachi model which was used for the final test of the developed process. The six model sections obtained from Hitachi incorporated approximately 230 pipe segments[1] and 160 pipe events. A general elevation view of the six model sections fully assembled is shown in Figure 2.1.

Extrapolation of costs associated with photographic, stereo-digitizing and data processing tasks (for parts of the model) revealed that piping geometry for all six model sections could be produced for $12,100. Utilization of a more productive computer controlled stereodigitizer (see paragraph 2.4.1) could reduce the cost nearly 25%. These costs include burdened labor and equipment useage but not G&A or profit.

E. DETAILS OF THE DEVELOPED PHOTOGRAMMRTRIC SYSTEM

E.l Desirable System Attributes

In the early stages of the project there were no preconceived ideas as to the best photogrammetric approach to dimensioning from models. A purely analytical process was considered as was a stereo system; both were described in the Interim Report. In evaluating possible solutions, a list of desirable characteristics was prepared. Some of these should apply to any dimensioning ***system;*** photogrammetric or otherwise.

a. The system and procedures should basically be the same regardless of whether the model is true-to-scale or wire and disc.

b. Drastic changes in current model building techniques should not be required.

[1]A pipe segment is generally considered to be any straight line run between two bends or a bend and a nozzle.

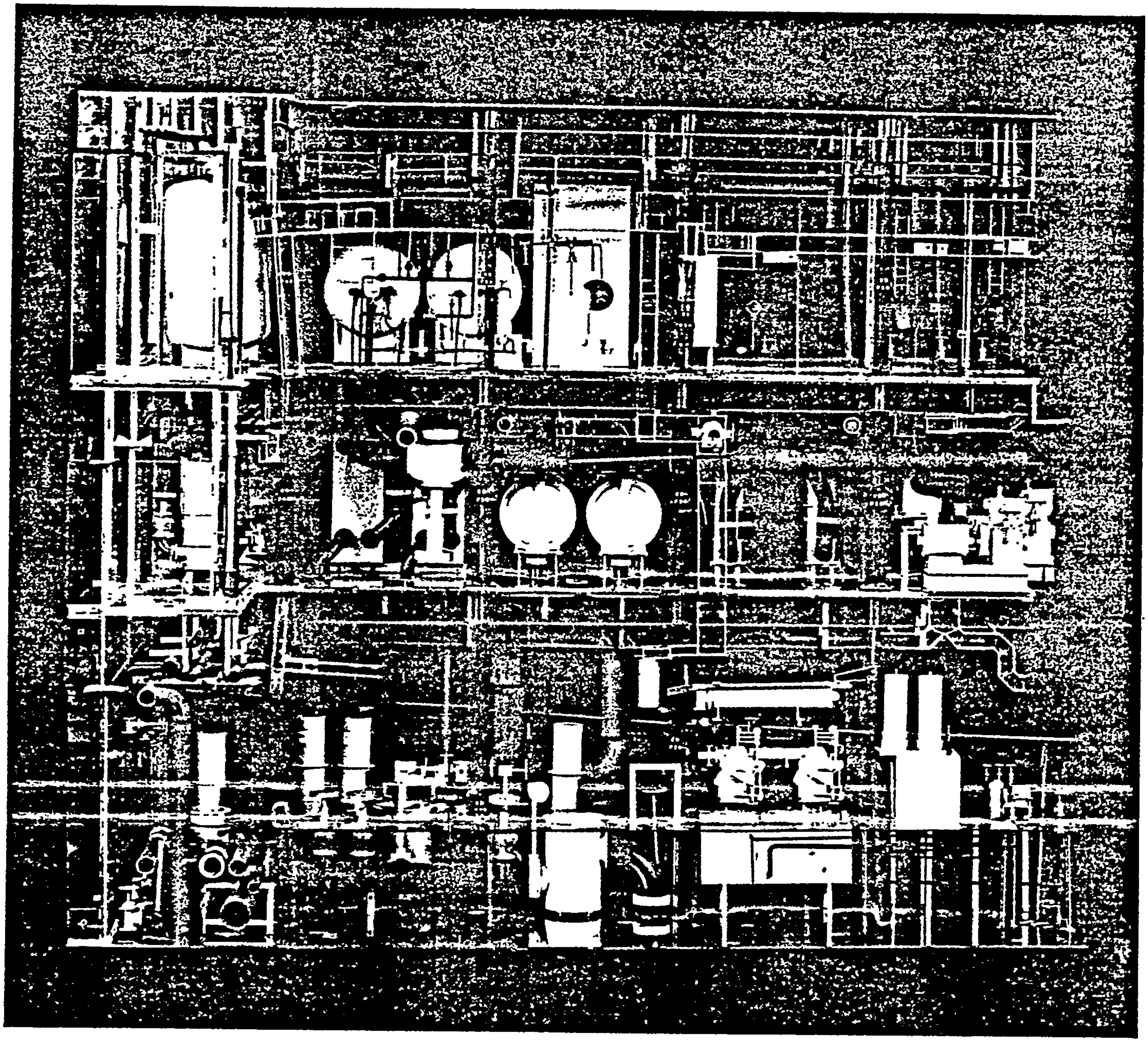


FIGURE 2.1: Six Fully Assembled Sections of the Hitachi Model. The entire model (not all obtained for the project) is comprised of 25 sections portraying the entire machinery space of an 18,930 DWT container ship. The particular sections shown represent the forward starboard portion of the machinery space from the tank top to the upper deck. These were used for the final test of the developed photogrammetric system. View is inboard looking outboard.

c. Specially built photogrammetric hardware should not be required.

d. The camera must have the ability to be focussed over a range of photographic distances.

e. Extensive preparation of the model should not be required.

f. Extreme care in positioning the camera or the model should not be required.

g. Black and white photographs should be used if it is possible to do so without seriously affecting productivity.

h Gathering of raw data (i.e. taking photographs) should be fast so as not to interfere with the use of the model by designers, planners, etc.

i. Digitizing from the photographs should be simple procedurally so that an expert photogrammetrist need not be employed.

j. The digitizing instrument should not be significantly limited in photographic focal length, allowable base between camera stations and lack of parallelism between optical axis of adjacent photographs.

k. Coordinate data produced by the system must be of sufficient accuracy so as *to* be compatible with manufacturing and installation needs.

l. The data must be formattable so as to be compatible with existing computer-aided pipe detailing and fabrication programs.

m. If possible, photogrammetric equipment should also be usable for other shipyard measurement tasks such as dimensioning large steel units.

E.2 Basic Conclusions Regarding the System

It was ultimately concluded that the best overall solution would be a stereo system in which the stereodigitizer was of the computer controlled variety. It was also concluded, however, that it was not possible as *a* practical matter to directly digitize data needed by automated pipe detailing systems, i.e. pipe centerlines, bend intersection points and centerline locations of pipe events. This led to the final conclusion that these data would have to be determined indirectly by manipulating data which could be more readily digitized. At this juncture

preliminary procedures were conceived and testing of these commenced. Procedures as well as hardware ultimately employed are described in the following paragraphs.

E.3 The Models

E.3.1 Descriptions

Initially experiments were conducted with a 4x2x2 ft. section of a floating nuclear power plant loaned to the project by Offshore Power Systems ("OPS") of **Jacksonville,** Florida. Work with this model allowed procedures to be tested and modified. Experimental stereodigitizing also provided data needed to test computer programs being prepared for the reduction of digitized data to coordinates of bend intersection points and centerline locations of pipe events.

While this experimental work was in process, arrangements were made with Hitachi Shipbuilding and Engineering Company, Ltd. to obtain portions of one of their design models of a ship's machinery space. It was deemed desirable to perform final tests of the photogrammetric system on a Hitachi model because of Hitachi's level of development in model engineering. Many of the desirable model building techniques set forth in paragraph 2.1 are state-of-the-art at Hitachi, particularly sectionalization.

Model sections obtained from Hitachi were from a 25-sectton 1:15 scale model of the machinery space for a 18,930 DWT container ship. The entire model measured 1.8 m in length, 1.8 m in breadth and 1.2 m in height. Three deck levels representing the forward starboard side of the model were obtained from Hitachi. Each deck level is sectionalized such that it is self-contained and may be further separated into two pieces comprising piping hung from the

overhead and machinery and piping related to the deck below. Hence, a total of six model sections were actually obtained. Figures E.1 and E.2 illustrate how the model is sectionalized. Figure 2.1 shows all six model sections fully assembled.

E.3.2 Preparation of the Hitachi Model

In the course of building models it is customary for a regular reference grid to be fit, as a minimum, upon the model base. On the Hitachi model the grid system is scribed into the plexiglas of every deck and overhead and on large vertical surfaces as well. The grid spacings correspond to 1 m water lines, 1 m buttock lines and a 0.8 meter frame spacing. To provide the photogrammetric solution with an absolute shipboard reference, selected grid intersections of each model section were fit with a few simple targets so that these "known" locations would be readily identifiable on the photographs. Two types of targets were employed but both satisfactorily served the same purpose. One was a self-adhesive (peel-off backing) target having an annulus-like bull's-eye upon a black background. The second type target was merely a reinforcing ring normally used to reinforce punched holes in paper. The ring actually only served to identify a grid intersection - grid lines within the ring were clearly visible on all photographs. Each type target was hand lettered with the ship's coordinates of the grid intersection to which the target was attached. This was done merely as a matter of convenience. Both types of targets are shown in Figure E.3.

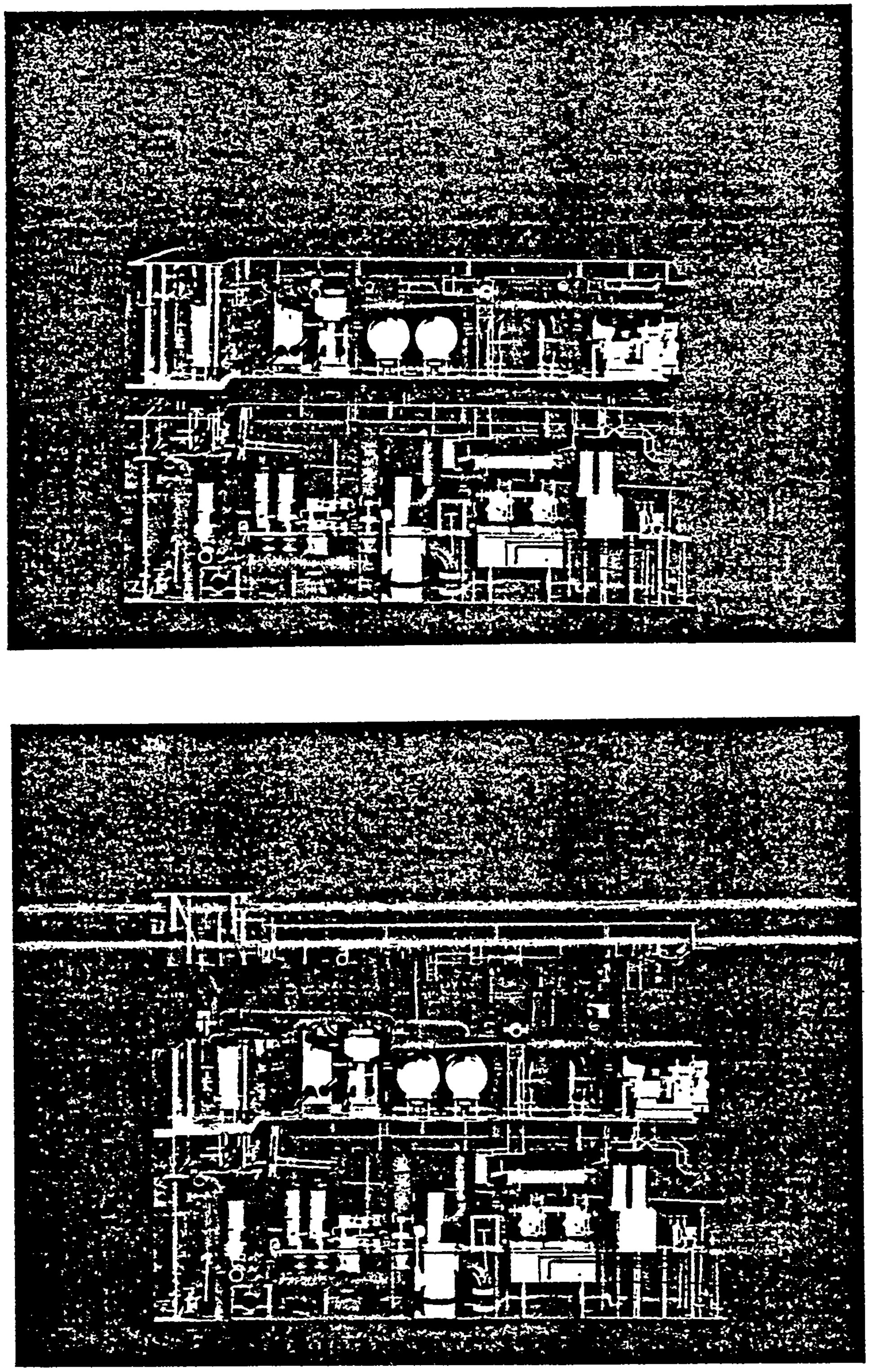
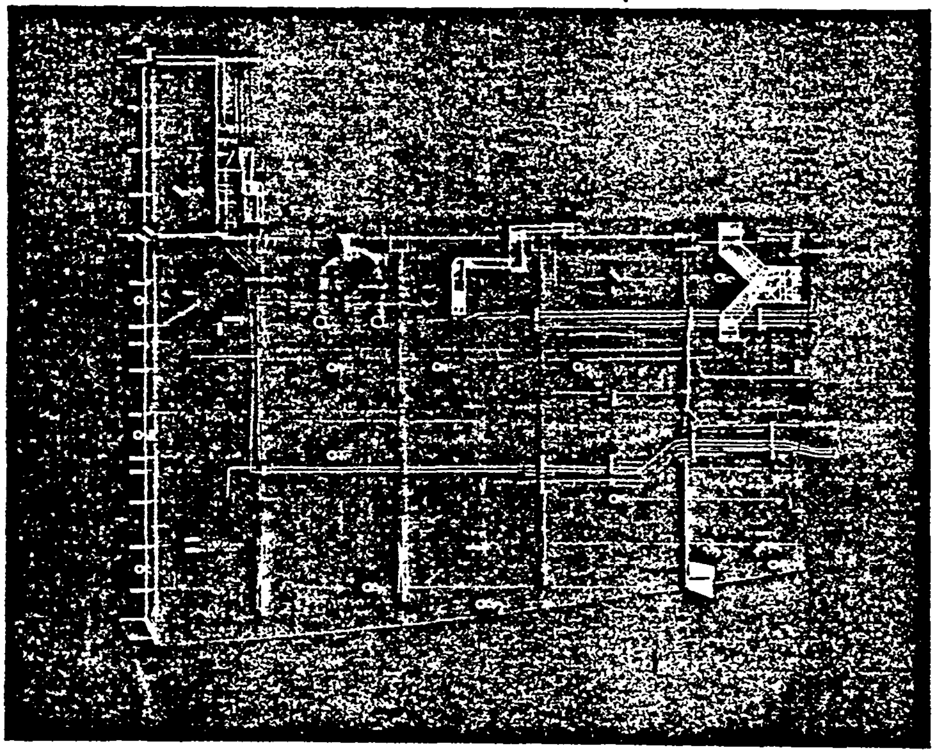


FIGURE E.1: Illustrating Sectionalization of the Hitachi Model. The upper picture shows how the model is sectioned horizontally through a deck. The particular split shown is through the third deck. The lower picture shows how the overhead below the second deck can be removed. Such sectionalization is standard between all deck **levels.**



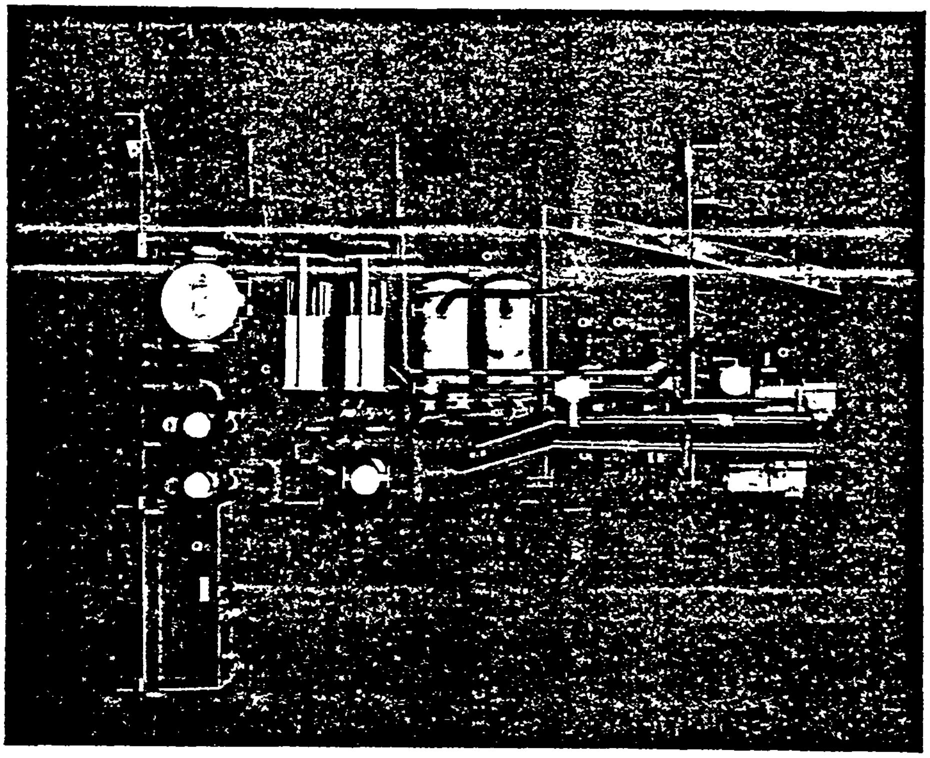
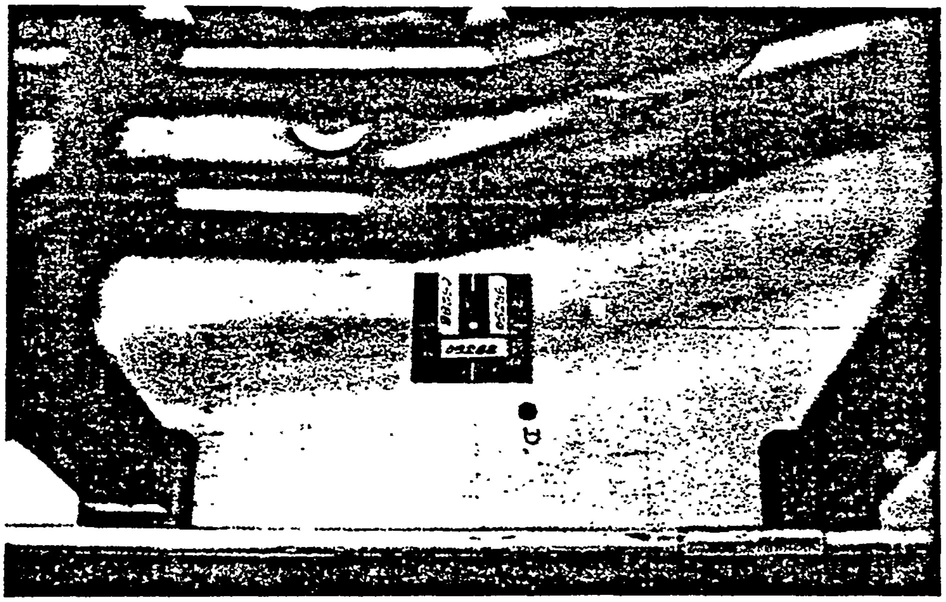


FIGURE E.2: Illustrating Division of the Hitachi Model Between Two Deck Levels. The upper picture is of an overhead (as if viewed from below). The lower picture is of the deck below (as if viewed from above). Particular sections shown lie between the second and third decks.



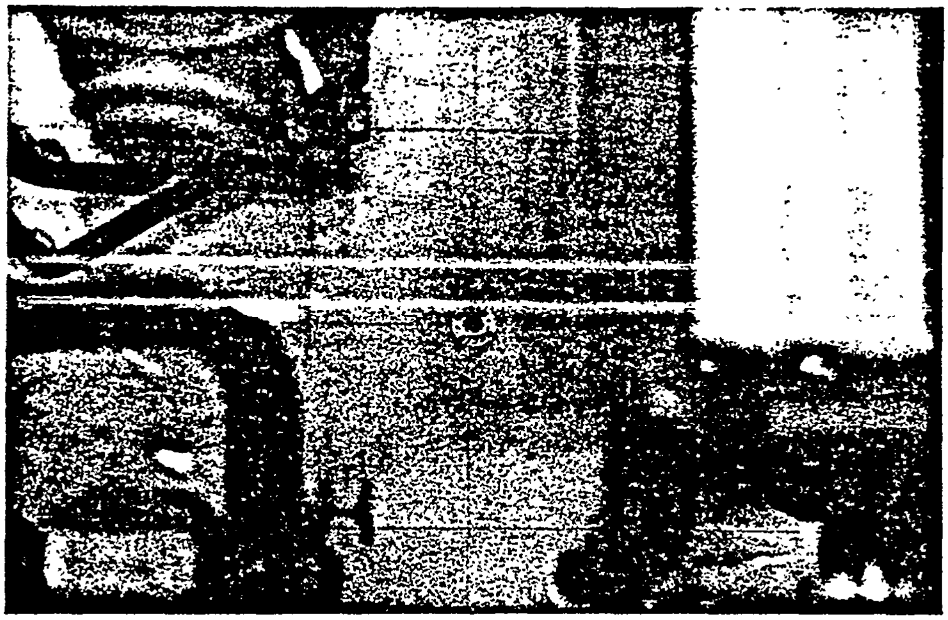


FIGURE E.3: Targets Signalizing Locations of Known Ship. Coordinates. The target shown in the upper illustration has a peel-off back which exposes a pressure sensitive adhesive. Registration marks are aligned with grid lines scribed on the model. In the lower figure an ordinary reinforcing ring circles a grid intersection which has been filled with red pencil. Both types of targets satisfactorily served the same purpose.

As will be seen later, several different photographic views of each model section are desirable. In order to accurately "match" these views to one another in the data processing phase, a few additional "tie-in" targets should be placed on each model section at well distributed locations which are likely to be seen in all photographic views. Targets placed at grid intersections can serve this purpose too, but oftentimes these cannot be seen in more than one or two views. Hence, the need for the extra "tie-in" targets. Such targets were not used on the Hitachi model but only because small discrete markings on the model served the same purpose.

To facilitate handling of a given model section for the photographic effort, the section was temporarily attached to a stiff board by means of small bolts. This allowed the section to be tilted and rotated while maintaining its rigidity. See paragraph E.4.3.

E.4 Photography

E.4.1 The Camera

All photographs of the OPS and Hitachi models were taken with the researcher's Wild P31 Universal Terrestrial Camera pictured in Figure E.4, but with the camera body removed from its mount. This particular camera was employed because of its ready availability. Nonetheless, compared to most other photogrammetric cameras, it is reasonably well suited to close-up photography of models. A similar camera manufactured by the Zeiss Jena works[1] would perhaps be better suited owing to its somewhat greater depth of field. Both the Wild and Zeiss cameras mentioned are characterized by virtually distortion

[1]The UMK 10/1318, sold in the U.S. through the Zena Company; see Appendix F.

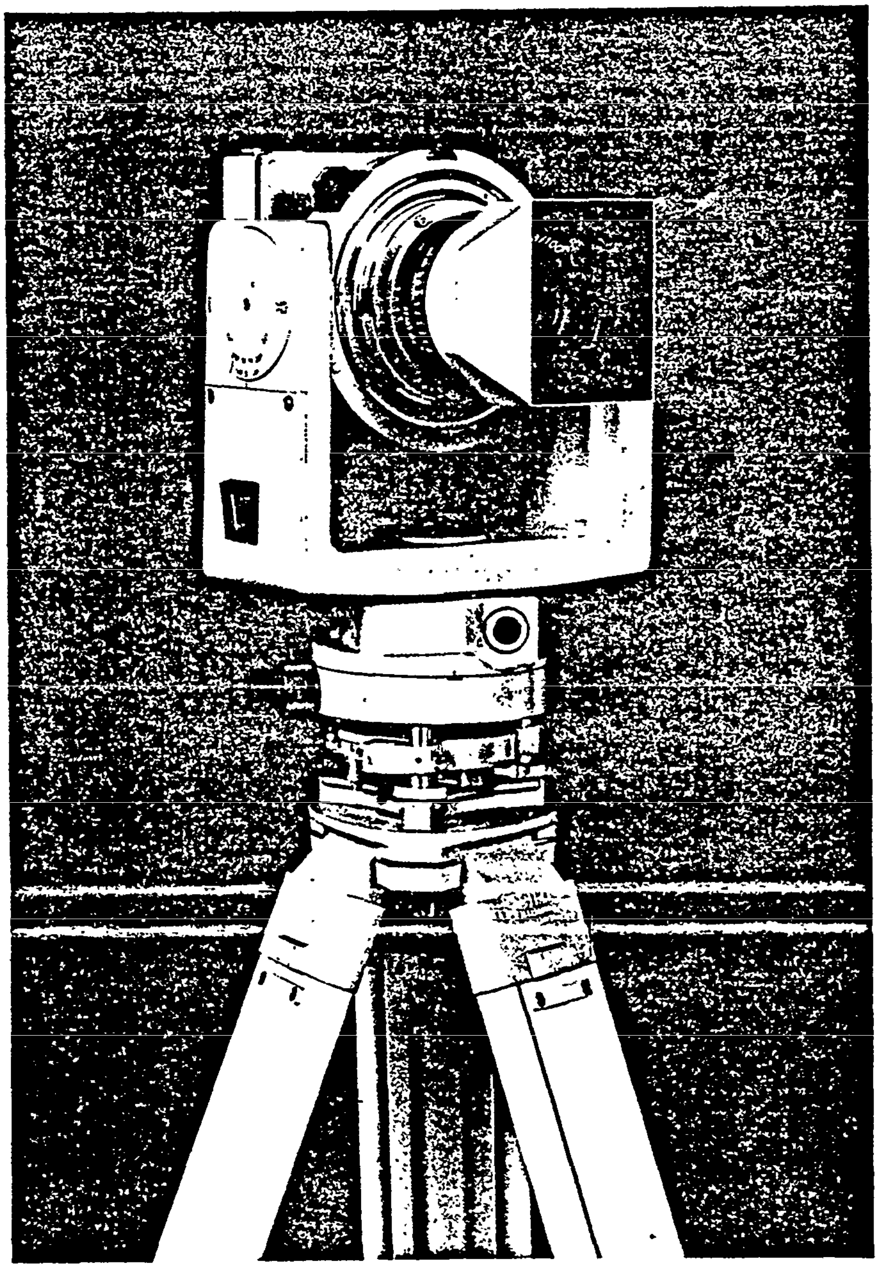


FIGURE E.4: The Wild P31 Universal Terrestrial Camera. This particular camera accepts single frames of glass or film, is focussable over a range of photographic distances and has a distortion free lens. The camera body may be removed from the yoke mount for hand-held use.

free lenses and their ability to accept glass plates *as* well as film for recording the imagery. Glass plates were used throughout this project because of their desirable dimensional stability. But, a large volume of production work could dictate the use of film for reasons of expense, ease of handling and storage.

E.4.2 Camera/Model Geometry

Rough calculations performed in advance indicated that a reasonable setup of camera stations relative to the model could be such that a single stereopair[1] would cover an entire model section. Basic tradeoffs considered were decreasing the camera-to-object distance for greater accuracy but with an increase in the number of photographs to expose and reduce owing to depth of field limitations at shorter ranges.

The geometry of the final setup is shown in Figure E.5. Two important additional considerations are incorporated in the plan shown:

a. The model is tilted so as to avoid as much hidden piping detail as possible. If photographs are taken with the camera axis in a plane parallel to the deck, piping in the foreground usually obscures piping in the background. This is because pipes are often run in common horizontal planes, particularly when hung from an overhead.

b. The distance between camera stations is smaller than desirable from an accuracy point of view. But, as a practical matter, the distance is limited by the need to digitize vertical piping in the foreground while viewing such pipes stereoscopically in the stereodigitizer. If the camera stations are too far apart, the left hand exposure will image the left side of a vertical pipe and the right hand exposure will 'image the right side of the pipe. Absence of common images on the two photographs renders it impossible to view such pipes stereoscopically and, therefore, digitize them.

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[1] One photograph taken from each of two adjacent camera stations such that the **optical** axes of the two photographs are nearly parallel.

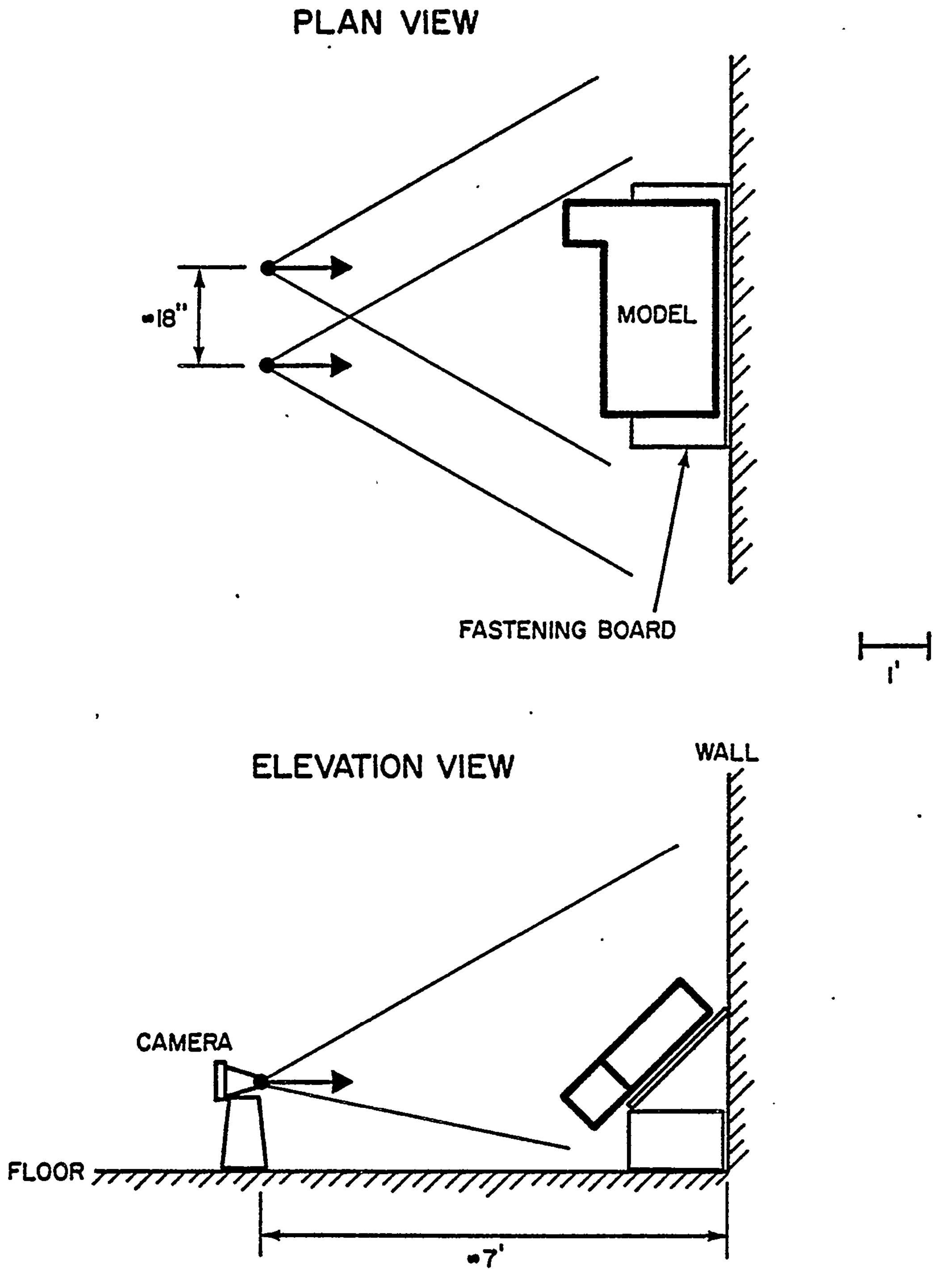


FIGURE E.5: Camera/Model Geometry. Trade-offs which must be considered are photogrammetric accuracy, number of photographs and depth of field, The model is tilted to avoid obscurations of the most distant (from camera) detail by detail in the foreground. A single camera was slid between camera stations to obtain the indicated exposures.

E.4.3 Procedures

Once a model section is attached to the fastening board it is set up as shown in Figure E.5. A picture (black and white) is taken from one of the indicated camera stations. The camera is then slid sideways to the adjacent camera station from which the second photograph of the stereopair is taken. The model section, still attached to the fastening board, is rotated 90 degrees and another stereopair is exposed. This process is repeated four times so that the model section is photographed from all four "sides".[1]

Figure E.6 illustrates the rotation process for the model section shown at the bottom of Figure E.2. Not shown in Figure E.6, however, are markings on the wall behind and around the fastening board. These markings are intended to provide contrasting detail on an otherwise featureless surface. Utilization of such markings aids orientation of adjacent photographs of a stereopair during setup of the stereodigitizer later on. Figure E.7 is a typical stereopair of the same model section. When these photographs were taken the background contrast was created by attaching a gridded mylar sheet to the wall. In earlier work with the OPS model, targets like the one shown at the top of Figure E.3 were attached *at* random locations on the wall. This was in fact a better approach since there can be no possible movement of the targets between photogrammetric exposures.

[1]A color snapshot is also taken each time a photogrammetric exposure is taken. The color shots are occasionally used later on to help interpret the black and white photogrammetric exposures.

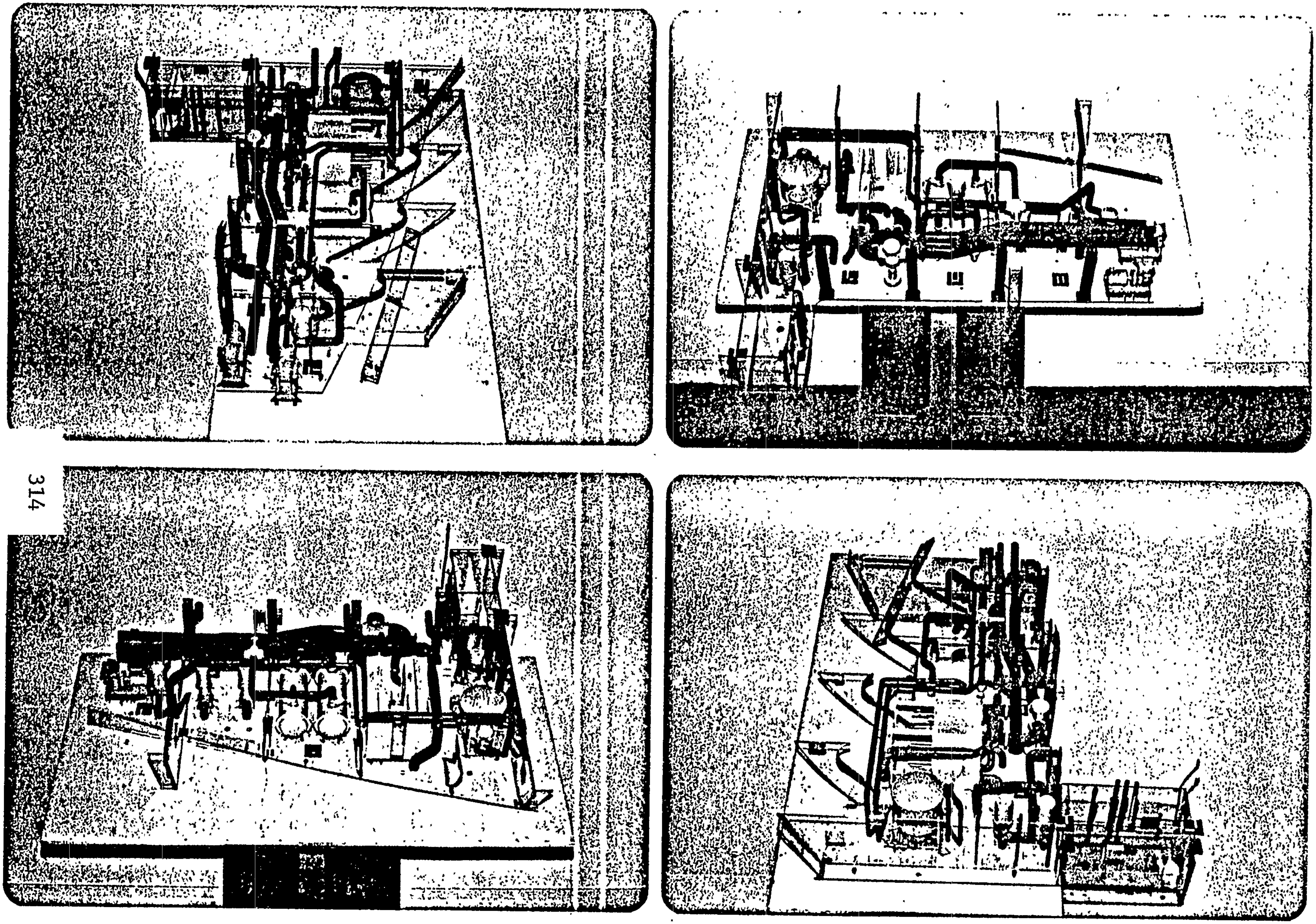


FIGURE E.6: Rotation of a Model Section for Exposing Four Successive Stereopairs. Four views avoid hidden detail, allow digitizing all "sides" of a pipe and permit uniform overall digitizing accuracy.

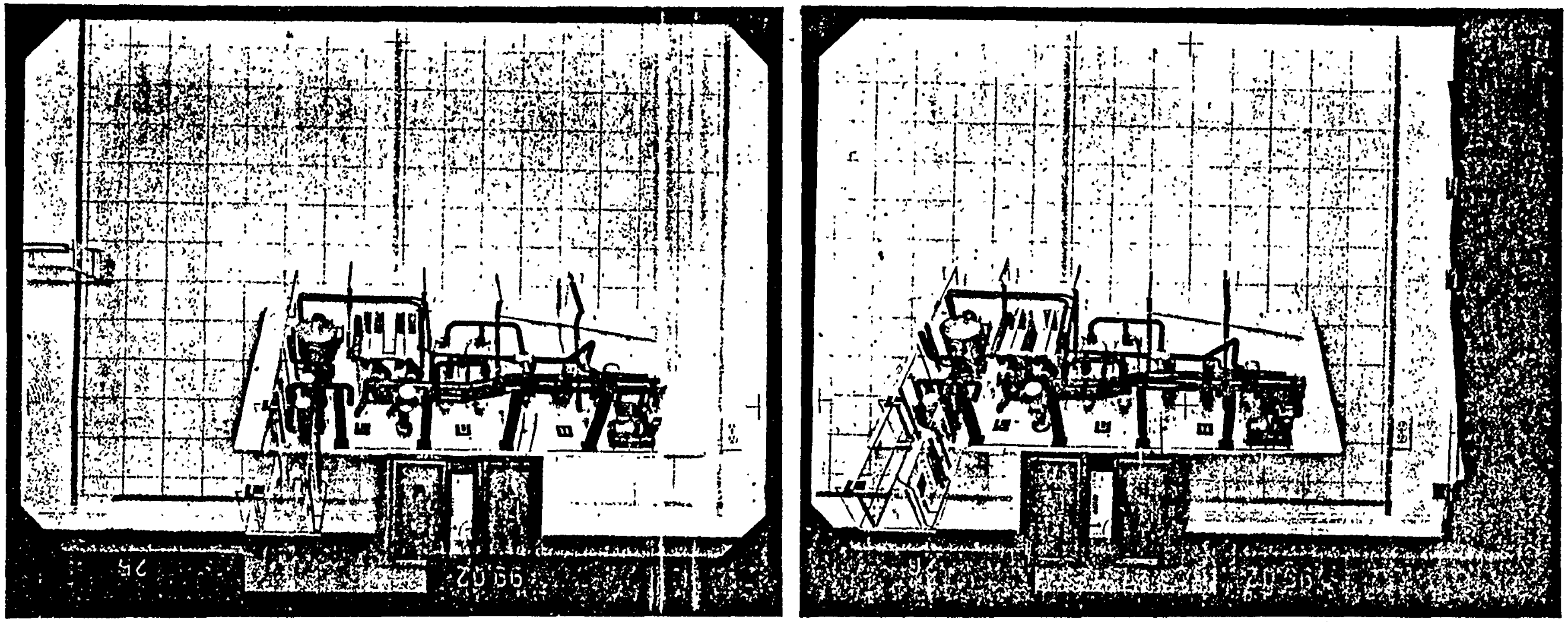


FIGURE E.7: A Typical Photogrammetric Stereopair. The gridded mylar sheet on the wall serves only to provide contrast on an otherwise featureless surface. Photographs are 1:1 prints from the original glass plate negatives.

While it may seem redundant to photograph each model section from four aspects, the process is fast and offers three distinct advantages:

a. It is unlikely that piping detail will be lost entirely. Detail obscured in one or two views will most likely be seen in the others.

b. As indicated earlier, data digitized on a pipe surface will eventually be fit with a cylinder in order to find the true centerline location of the pipe segment. This fitting process is much more reliable when there are data on all "sides" of a pipe segment rather than only on the one side visible in a single stereopair.

c. Data digitized within any given stereopair will have a range of accuracy which decreases from foreground to background detail. If data from all four stereopair are merged, the overall accuracy of all detail digitized becomes more uniform.

E.4.4 Lighting

Bounce lighting of the model is the most desirable. This is accomplished very easily by directing strobe lights toward the walls and ceiling away from the model section. Light impinging upon the model is, therefore, coming from all directions and the resulting negatives are virtually free of shadows. Freedom from shadows is desirable so as to avoid losing detail and also to eliminate the possibility of confusing a pipe's shadow as *an* actual pipe.

Because bounce lighting is inefficient relative to direct lighting, it is desirable to employ a fairly high powered strobe unit so that sufficient light can be output in a single pulse: It is also desirable to employ a digital light meter to aid rapid determination of proper exposure without experimenting.

[1]A 1200 watt-second unit was used to light the OPS and Hitachi models.

E.4.5 Emphasis on Simplicity

It is most important to emphasize that all of the above described preparations and procedures are very simple. They can be carried out anywhere without a specially prepared room. Although setup of the proper model/camera geometry is planned in advance, implementation does not require precise measurements; an ordinary carpenter's tape or desk ruler may be used without exercising much care. Bounce lighting is achieved without special precautions in aiming the strobe head(s). Even "eyeball" aiming of the camera is adequate. Figure E.8 illustrates the overall setup for one of the Hitachi model sections. While the setup may appear experimental it need not be any more sophisticated for actual production work.

E.5 Preparation for Stereodigitizing

To permit the operator of the stereodigitizer to rapidly digitize desired data, specific "instructions" should be prepared prior to start-up of digitizing from a given pair of photographs. Such preparation relieves the operator of a multitude of decisions as to what to digitize and what identifiers to attach to digitized data. It also greatly simplifies his housekeeping tasks; e.g. what detail has or has not been digitized. Pre-preparation permits maximum productivity of the stereodigitizer and of the operator's unique expertise to view stereoscopically and digitize in three dimensions.

E.5.1 Photo Enlargements

For familiarization and orientation purposes the operator of the stereodigitizer prefers to have a photographic print from one of the photographs comprising a stereopair to be digitized. Because

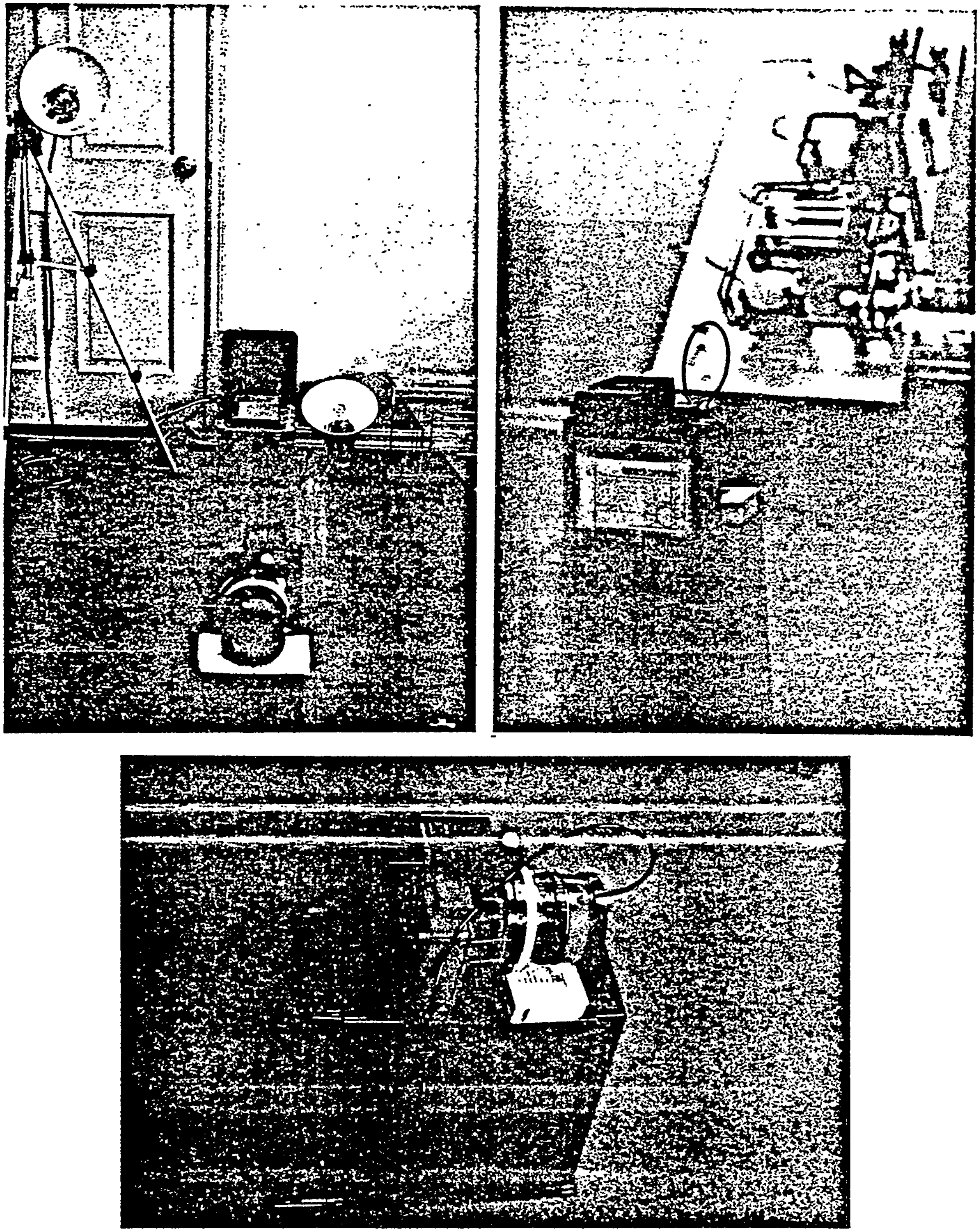


FIGURE E.8: Overall Views of Setup for Taking Photographs of a Typical Model Section. In the upper left the two heads of the ***strobe*** unit are purposely aimed away from the model in order to create "bounce" lighting of the model. The upper right and lower illustrations depict the camera setup. A digital strobemeter rests atop the camera. Note the simplicity of the entire arrangement.

the original negatives are rather small it is preferable to provide him with an enlargement, particularly of just that portion of the negative showing the model proper. Experience has shown that an 11x14 inch enlargement is ideal. This is a practical. size for a photographic laboratory to produce, it is easy to handle and it provides a sufficiently large scale picture of the piping that uncongested line tracings can be prepared in the form of transparent overlays.

E.5.2 Transparent Overlays

Specific detail to be digitized must be identified for the operator of the stereodigitizer. One way in which this can easily be accomplished is *to* mark the detail on transparent overlays[1] to the 11x14 inch enlargements. Four types of detail must be identified:

a. control points; i.e. targets at locations of known ships coordinates (see paragraph E.3.2),

b. tie-in ***points;*** i.e. targets placed ***to*** aid matching of data digitized in different stereomodels (see paragraph E.3.2),

c. pipe surfaces, and

d. pipe events.

Figures E.9 and E.10 respectively show a typical photo enlargement and one of its transparent overlays. The use of colors on the overlay serves no other purpose than to aid the operator of the stereodigitizer in following a given pipe run. Also note that a very simple numbering scheme is employed; one and two digit numbers for targetted points and a pipe

[1]Pipe events are annotated on a separate overlay simply to avoid congestion.

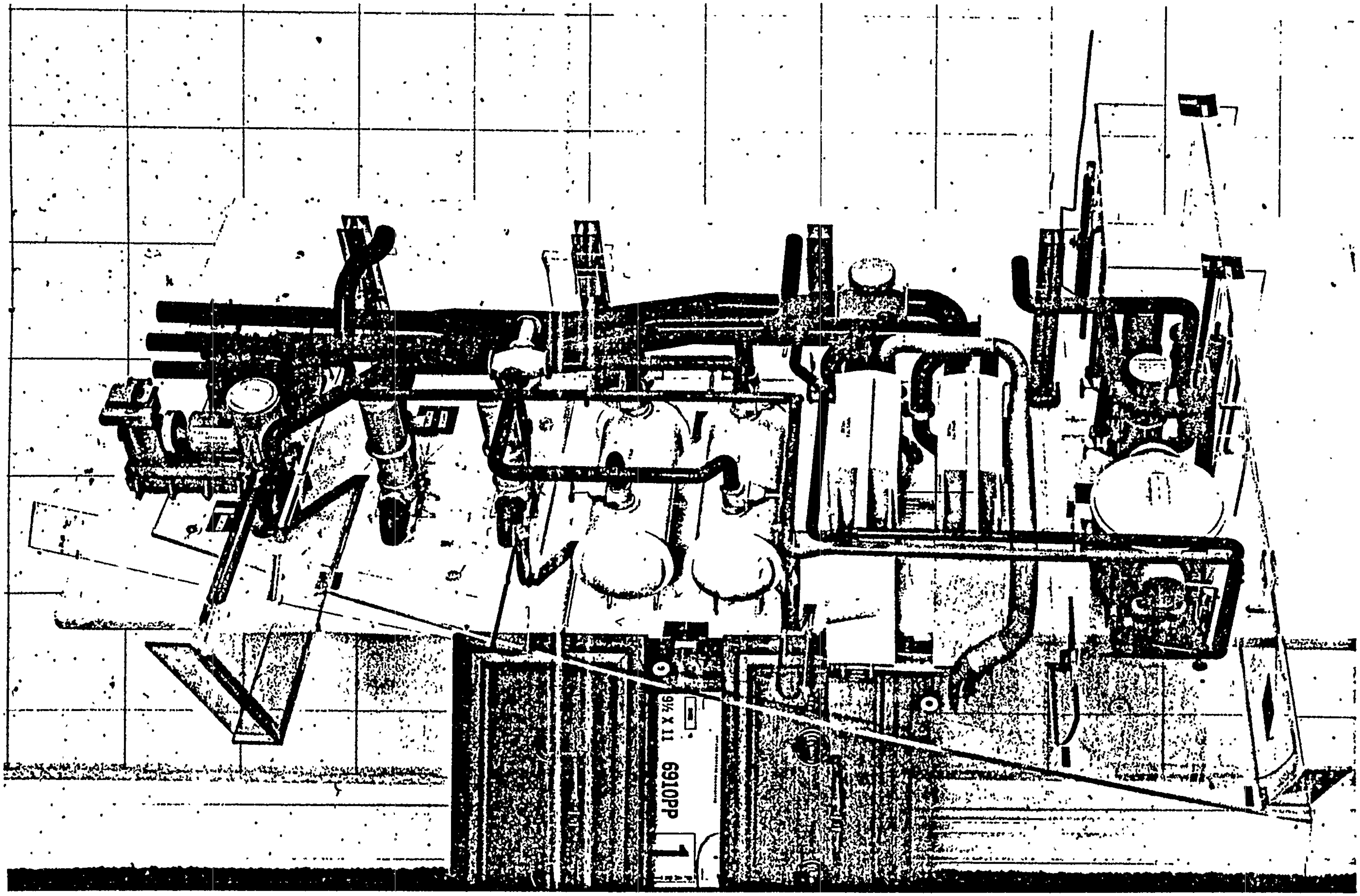


FIGURE E.9: Typical Enlarged Print for Stereodigitizing Preparation

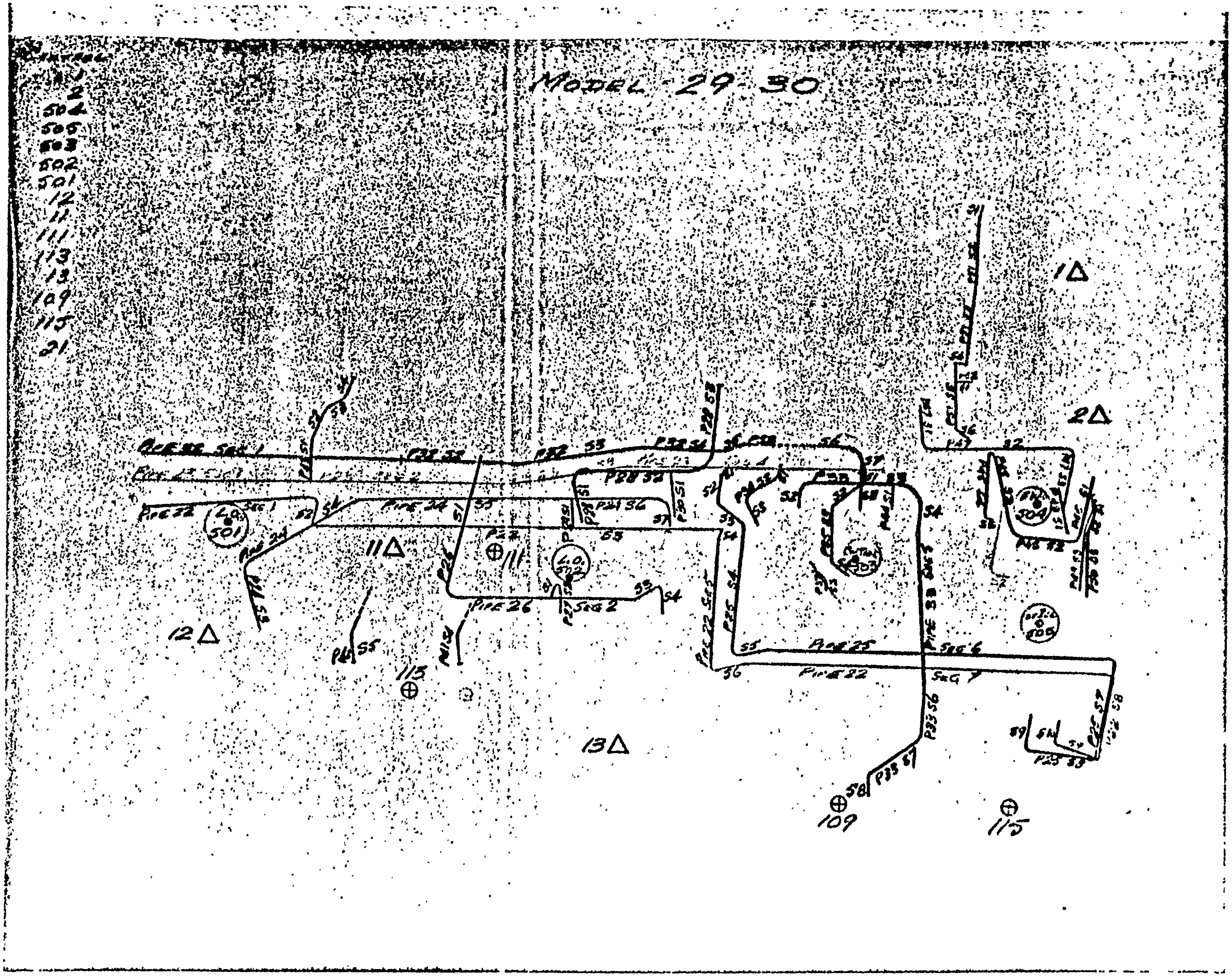


FIGURE E.10: Copy of Transparent Overlay to Enlarged Print Shown in Figure E.9.

number/segment number designation for each straight line portion of a pipe run.

Preparation of overlays is best done by a person familiar with the model. This is because familiarity allows rapid interpretation of a single black and white enlargement for which an overlay is being prepared. (It should be assumed that the model may not be available for other than the picture taking operation.) A person not familiar with the model can also prepare overlays, but more frequent reference *to* the color snapshots will be required.

E.5.3 Precomputing Stereodigitizer Settings

When a pair of photographs are placed into a stereodigitizer, digitizing cannot proceed until the exact position and attitude of one photograph relative to the other is determined first. If the stereodigitizer employed is of the computer-controlled variety, this step can be quickly accomplished by the operator interacting with the instrument's computer. When an analogue stereoplotter is used as the stereodigitizer, this relationship between the photographs must be determined in advance of presenting the photographs to the stereodigitizer.[1] Such predetermined values may be set directly into dials of the analogue stereoplotter.

Because a computer-controlled instrument was not used for this project, precalculation of settings for an analogue stereoplotter was necessary. This involved two steps. First, each of two negatives comprising a stereopair were measured individually on the researcher's monocomparator shown in Figure B.2. Measurements made on each

[1]Theoretically the relationship can be determined empirically at the analogue stereodigitizer. But, this is a very time consuming trial and error process for the type of photographs involved.

negative were simply the locations of a few discrete points (e.g. targets and/or grid intersections on the model and wall behind) whose images appeared on both negatives. In the second step these measurements were processed through an existing computer program to arrive at the needed stereodigitizer instrument settings.

E.6 Stereodigitizing

E.6.1 Hardware

All stereodigitizing work was performed on a Wild Al0 analogue stereoplotter like the one shown in Figure B.l. A computer-controlled instrument was preferred, but the Al0 was used because of its convenient availability. Bosworth Aerial Surveys, Inc. of Lake Worth, Florida provided valuable man power assistance to the researcher and also made their Al0 available for experimental and production work on relatively short notice.

Although Bosworth's A10 is not computer-controlled, it is on-line with a mini-computer. To aid the stereodigitizer operator, programming was prepared by Bosworth to present certain commands or "prompts" to the operator on a CRT beside the AlO. Answers to these prompts are entered on the keyboard of the CRT by the stereodigitizer operator. These data plus XYZ coordinates digitized by the operator while viewing the stereomodel are automatically fed directly to the mini-computer and stored on a disc. Inasmuch as the researcher's computer is practically identical to Bosworth's, transfer of data to the researcher's facility for subsequent data processing was simply a matter of hand carrying a disc cartridge.

E.6.2 Digitizing Sequence

Because of preparations made in advance (see paragraph E.5) the stereodigiting work is rather routine and proceeds rapidly.

For each' stereomodel the following sequence is typical:

a. load glass plate negatives in photo carriers of the stereodigitizer

b. manually dial precomputed instrument ***settings*** into the stereodigitizer (see paragraph E.5.3)

C. make fine adjustments to the precomputed settings while visually inspecting the stereomodel

d. initialize the prompting program from the CRT keyboard and answer questions such as stereomodel number and types of detail to be digitized first

e. digitize each targetted point; enter its number via the CRT keyboard, find the point in the stereomodel and depress the "record" foot pedal

f. advise the prompt program, via the CRT keyboard, that pipes will be digitized next

g. enter the pipe number at the CRT keyboard

h. enter the first segment number at the CRT keyboard

I. Digitize points on the surface of the pipe segment

j. repeat steps h and I for as many additional segments of the present pipe run that are visible in the current stereomodel

k. repeat steps g through j for all remaining pipe runs within this stereomodel

1. advise the prompt program that events will be digitized next

m. advise the prompt program of the pipe and segment number for which events will be digitized

n. advise the prompt program of the event number to be digitized

0. digitize either one or two points on the present event

P. repeat steps n and o for as many additional events on the present pipe segment that are visible in the current stereomodel

q. repeat steps m through p for all remaining pipe segments having visible events

r. advise the prompt program that the current stereomodel is completed

E.6.3 Specific Procedures for Pipe Segments

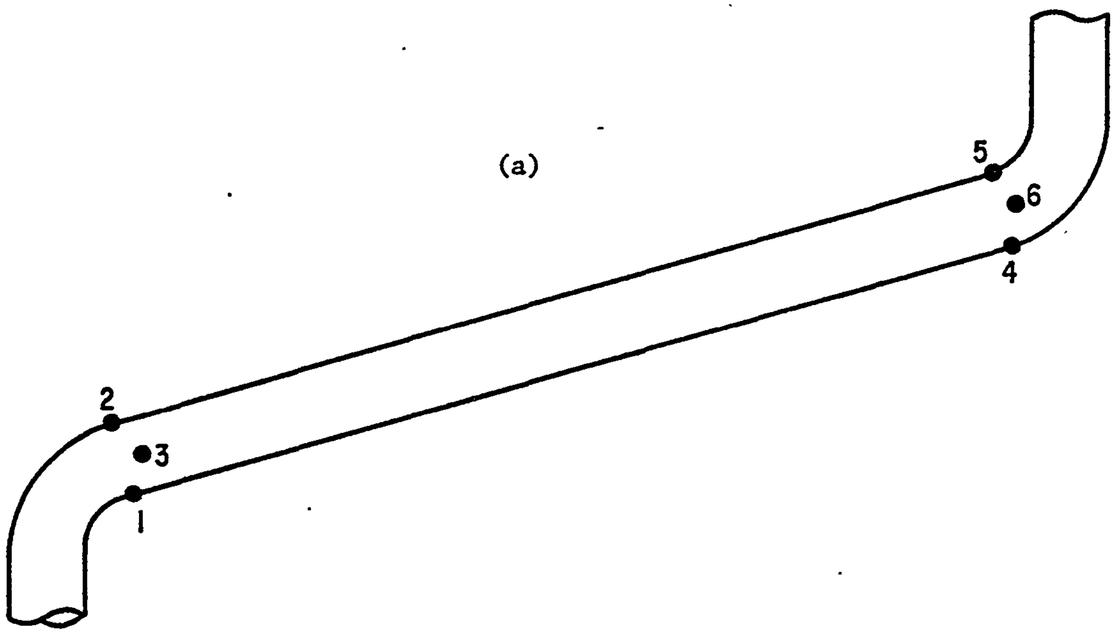
when digitizing a pipe segment it is preferred to read six points (within each stereomodel in which the segment appears) in the approximate locations shown in Figure E.lla. The notion of "approximate" is emphasized since obscurations by other detail of the model oftentimes dictate deviations from this scheme. Later on in the data processing a cylinder is fit to all points digitized on a pipe's surface in order to find the location and orientation of the centerline of the segment. That program makes no rigid assumptions as to the locations of digitized points, but it does use the ordering of the first points encountered for a pipe segment as follows:

a. points 1 and 2 are used to obtain an estimate of the diameter of the pipe segment

b. points 1 and 4 are used to obtain an estimate of the location and orientation of the segment

Estimates obtained in this way are then refined in the cylinder fitting process. Because of obscurations, actual locations of digitized points could be as shown in Figure E.1l.b. Note that approximations for diameter, location and orientation can still be obtained.

It is *a* matter of practical importance that digitized points be reasonably close to their respective bend intersection points. This is because the points of real interest, i.e. the bend intersection points themselves, will eventually be computed by intersecting calculated centerlines of adjacent pipe segments. The accuracy of the calculated centerlines will be greater if cylinders are fit to widely separated (lengthwise) digitized points. Theoretically the accuracy would also be higher if additional points



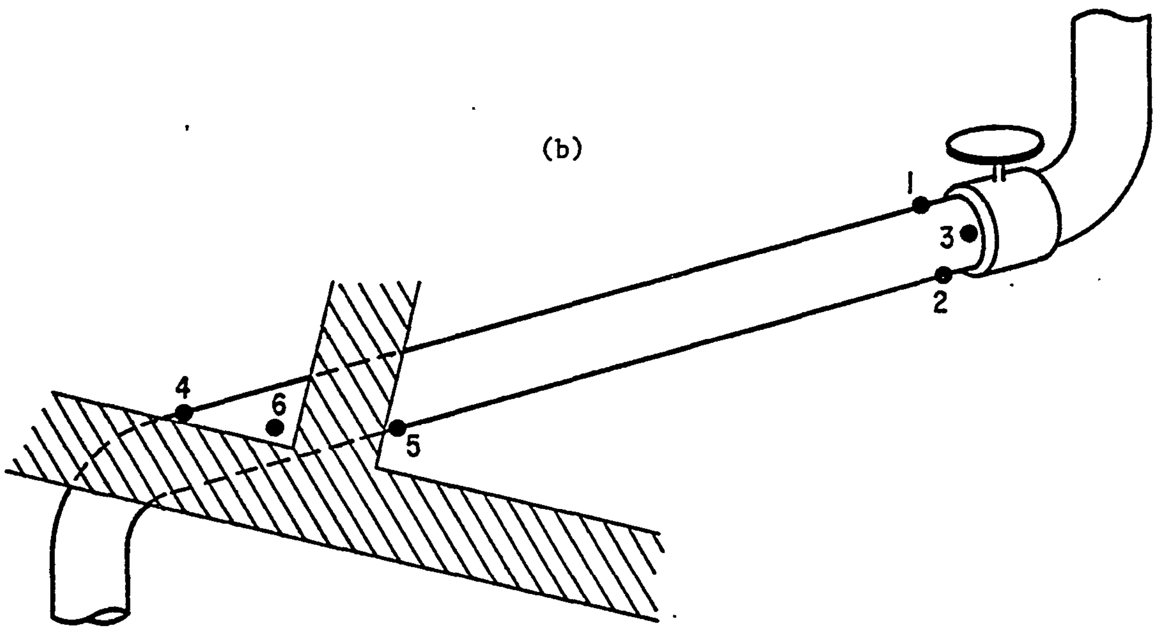


FIGURE E.11: Approximate Locations of Points Digitized on a Pipe Segment. The upper figure indicates ideal locations, in any one stereomodel, near the ends of the segment. As a practical matter, data are taken wherever the pipe segment is visible such as in the lower figure.

are digitized. But, the obvious choice of locations for such additional points, i.e. approximately midway along a pipe segment, usually works to the detriment of the process. Curvature in a modeled pipe, particularly a long run of small diameter, invalidates the concept of cylinder-fitting.

E.6.4 Specific Procedures for Pipe Events

Unlike pipes, pipe events are usually digitized only in one stereomodel rather than four. Decisions as to which events are to be digitized in which stereomodels are made at the preparation stage. Since surfaces are not fit to pipe events in the data processing stage, there is no need to digitize data on all 'sides' of an event.

Only one or two points are digitized on each event. The data processing program simply constructs a line in space through the digitized point(s) such that the line is perpendicular to the previously computed location and orientation of the pipe segment to which the event belongs. For an event with a single digitized point, the location at which the perpendicular strikes the centerline is the centerline location of the pipe event. If an event has two digitized points the program averages the two results. This computational scheme implies, therefore, that the operator of the stereodigitizer decides whether an event may be a "one point event" or a "two point event". With this.freedom of choice the operator can digitize an event such as a symmetrical valve with a stem simply by digitizing one point on the stem. Other symmetric events without such a center-defining feature are digitized as two point events; one point on each of two symmetrically located (lengthwise along the pipe) faces and/or edges.

E.7 Data Processing

Of necessity many details of the data processing functions have already been explained because they directly influenced all prior tasks from preparation of the model through stereodigitizing. Hence, following discussions of the data processing steps are expanded only to the extent deemed necessary to understand the logical progression of the calculations.

For each model section the data processing steps proceed in the following order:

a. By means of a three dimensional coordinate transformation program, all digitized data in stereomodel number two are put into the coordinate system of stereomodel number one. Similarly, data for stereomodel number three are put into the coordinate system of stereomodel number one and data for stereomodel number four are put into the coordinate system of stereomodel number one. This step is required because each view (stereomodel) of a given model section is digitized in its own arbitrary coordinate system whereas all data from all four stereomodels eventually need to be in a single common coordinate system.

   The basis for transforming data from one stereomodel to the coordinate system of another is by best-fitting the two sets of data at the tie-in targets common to both sets of data. This transformation process is actually comprised of two distinct steps. First, considering only the tie-in targets common to the two sets of data, the program determines seven transformation constants (3 shifts, 3 rotations and a scale factor) which, when applied to the second set of data, will convert it to the coordinate system of the first set of data in such a way as to minimize any remaining differences between coordinates of tie-in targets in the first set of data and transformed coordinates of tie-in targets in the second set of data. Once the seven constants are determined, they are then applied to all data in the second set so as to convert them into the coordinate system of the first set of data.

b. By means of the same three dimensional transformation program described above, all data resulting from step "a" are transformed into the ship's coordinate system. The seven transformation constants are determined by best-fitting coordinates (from step "a") of the targetted grid intersection points to the known or true ship coordinates for these grid intersections. Once the transformation constants are determined they are applied to all data from step "a" to produce ship's coordinates for every digitized point.

see paragraph E.3.2.

c. At this point in the data processing the data, even though in a common (i.e. ship's) coordinate system, are very disorganized. Hence, the next data processing step is to reorder the data so that all data belonging to a given pipe segment are collected together. This is merely a sorting operation; no calculations are performed with the data.

d. Now that all data belonging to a given pipe segment are collected together, they are input to a cylinder fitting program whose primary function is to determine the location and orientation of the centerline of the cylinder which best-fits all points belonging the particular pipe segment being processed. The basis for the calculation is that of finding the radius and centerline location and orientation of a perfect cylindrical surface which minimizes the perpendicular departures of the points from the perfect surface. Computed centerline locations and orientations for all pipe segments are stored in a separate data file for subsequent use in the next two data processing steps.

e. Wherever there are two adjacent centerlines of segments belonging to the same pipe run, the segments are numerically extended in three dimensional space so as to find their point of intersection. To be more correct, this "intersection" is actually the point of closest approach since it is unlikely that two lines in three dimensional space will intersect exactly. The calculated intersection point is the so-called bend intersection point and- is one of the principal end products desired of the photogrammetric dimensioning process (see paragraph 1.5). Figure E.12 illustrates how bend intersection points are calculated.

f. Centerline locations of pipe events are considered next. Data (after step b) belonging to a given event are matched with centerline data contained in the data file created in step d. This is done simply by finding the proper pipe/segment number in the centerline data file. Computation of the centerline location of the pipe event then proceeds as described in paragraph E.6.4. These locations are the second principal end products desired of the photogrammetric dimensioning process (see paragraph 1.5).

E.8 Evaluation of End Results

Experimental stereodigitizing was performed with the oPS model on two different occasions. Two different digitizing sessions were also conducted using the Hitachi model. Although all six sections of the Hitachi model were not entirely digitized, data collected and experience gained were adequate to draw definite conclusions.

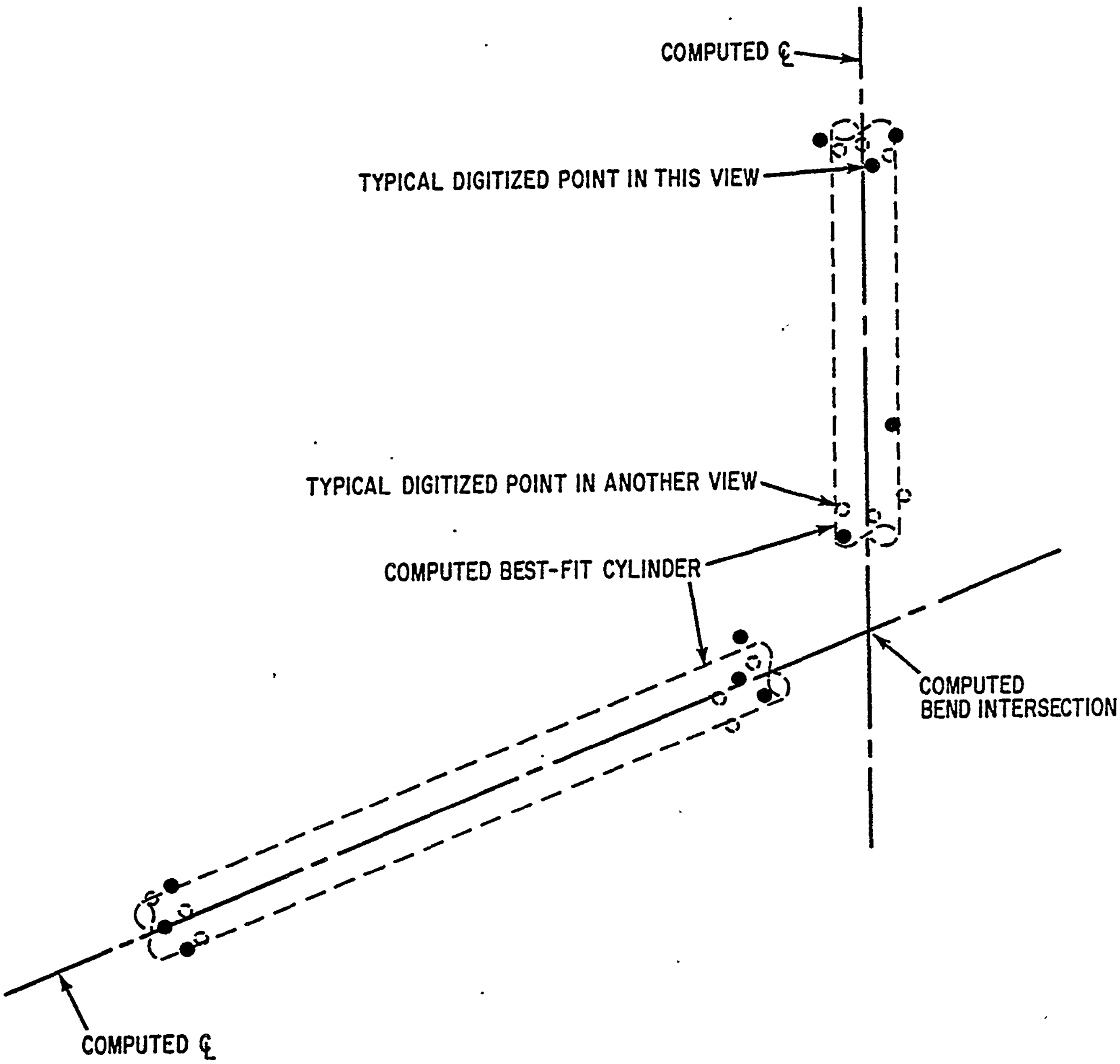


FIGURE E.12: Illustrating How Bend Intersection Points are calculated. A cylinder is best-fit to digitized points on a pipe segment to find the location and orientation of its centerline. Centerlines of adjacent pipe segments are then extended to find the bend intersection point. Although the illustration is two dimensional, digitizing and calculations are performed in three dimensional space.

E.8.1 Accuracy

One means for assessing the accuracy of data derived from the photogrammetric process was to calculate space distances between adjacent bend intersection points in the same pipe run. That is, computed XYZ coordinates of adjacent bend intersection points (Figure E.12) were used to compute the distance between the points. The same distances were also scaled by hand directly from the model and then compared to the calculated values.

Initial comparison of computed versus manually measured distances were astonishing. Despite particular care in taking the manual measurements it was found that they were replete with blunders of various sorts. Nearly every one of the errors, however, were directly traceable to the fact that pipe lengths cannot be directly measured by hand on the model. In the best of instances such as two adjacent 90 degree bends with no obstructions to hinder manual measurement, it is still necessary to apply a correction for the diameter of the pipe[1] and to scale the measurement to on board length. Even these two seemingly simply corrections were sometimes made incorrectly or forgotten altogether. As a practical matter, most distances are much more difficult to measure because of congestion within the model. This introduces the need to measure to offsets and/or to accumulate partial length measurements, each admitting additional chances for error. Finally, the most persistent cause for error in manual

[1]Because, for example outside of bend to outside of bend is measured.

measurements was associated with bends other than 90 degrees, particularly shallow bends. Because such bend intersection points are physically non-existent in the model and because they cannot be inferred as accurately as a 90-degree bend, the manual measurement' is virtually to an estimated location for the bend intersection.

After rectifying errors in the manual measurements as best as possible, differences between 86 photogrammetric and manually obtained distances between bend intersection points averaged 8.4 mm (0.33 inch) with a maximum difference of 40.0 mm (1.57 inch) on board. Because the manual measurements are still of questionable accuracy to be used as a base for comparison, it is fair to state that the actual accuracy of the photogrammetric results is quite likely to be better than the reported average and maximum differences.

'A similar comparison scheme was employed for pipe events. Computed XYZ coordinates of the centerline location of a pipe event and computed XYZ coordinates of the nearest in-line bend intersection point were used to compute the distance from the bend intersection point to the event. Twenty-four such distances, when compared to the same distances obtained by manual measurement of the model (after corrections for blunders) revealed an average difference of 12.6 mm (0.50 inch) and a maximum error of 28.0 mm (1.10 inch). As in the case of pipe lengths, the photogrammetric data are probably better than these figures might imply.

E.8.2 Completeness

The photogrammetric scheme outlined in this Appendix allows four chances to capture data for any pipe segment or event even though it may be partially obscured in all four instances (i.e. all

four stereomodels). Moreover, there are no rigid requirements[1] as to where data must be taken in any one of these views. Because of this general approach-to the problem, virtually all piping detail can be dimensioned by the photograrommetric process. Even if an occasional detail is not captured, this presents no significant difficulty because provision has been made to permit merging manual measurements or .a-priori knowledge of such detail into the computer data files.

E.8.3 Cost (Circa August 1980)

By extrapolation of experience with the Hitachi model it is projected that piping geometry for all six model sections (Figure 2.1) can be produced for $12,100 excluding G&A and profit. This figure covers labor and expenses for all phases of the work from photography through data processing. Data for approximately 230 pipe segments and 160 pipe events would be the end products.

It must be emphasized that the above projection is based upon utilization of the system described in this Appendix. As has already been stated, use of the Wild Al0 as the stereodigitizer was a matter of convenience (paragraph E.6.1). Had a computer-controlled instrument such as the one shown in Figure E.13 been employed, the total cost for producing data for all six model sections is estimated to be about 25% less. Table E.1 summarizes costs by tasks depending upon which type instrument is employed.

[1] But, there are preferred locations.

TABLE E.1

Projected Costs for Photogrammetric Dimensioning of the Hitachi Model Shown in Figure 2.1

Task	Cost With Analogue Stereodigitizer	Cost With Computer-Controlled Stereodigitizer
Photography	$ 1,405	$1,405
Precalculate Settings	2,955	N/A
Preparation and Digitizing	5,300	5,300
Data Processing	2,440	2,440
TOTALS	$12,100	$9,145

It is also significant that the first cost for hardware is significantly different for the analogue and computer-controlled stereodigitizer systems. The more productive computer-controlled system is also cheaper by a factor of nearly two owing to the fact that it does not require a comparator for precalculation of instrument settings and that its computer can be used for data processing as well as operation of the stereodigitizer itself. Table E.l summarizes hardware costs.

E.9 Concluding Remarks

The photogrammetric system and procedures described in this Appendix certainly confirm that photogrammetric dimensioning of distributive systems models is practical, particularly in view of alternate methods described in Appendix D. It must be said,,however, that variations of photogrammetric procedures described are entirely feasible. That is, the described procedures are not necessarily the only ones which will produce acceptable end products.

TABLE E.2

First Costs for Photogrammetric Hardware

Item	Analogue Stereodigitizer System Used on this Project		Computer-Controlled Stereodigitizer System	
Camera	Wild P31 (Fig. E.4)	$ 23;000	Zeiss Jena (Para. E.4.1)	$ 30,000
Comparator	Kern MK2 (Fig. B.2)	28,000		N/A
Mini-Computer	Data General or Digital Equip. Corp.	28,000		N/A
Stereodigitizer	Wild A10 (Fig. B.1)	190,000	Bendix US2 (Fig. E.13)	110,000
TOTALS		$269,000		$140,000

Because the basic objective of this project is to demonstrate the practicality of photogramnetric dimensioning, many small details, which must eventually be considered in production work, have been ignored. For example, computation of flange orientations, in-line discontinuities such as reducers, data validation checks, etc. These are viewed as being data processing functions which need not be addressed within the scope of this project. It is clear by now that photogrammetry provides a viable three dimensional digitizing process that can generate all data needed to satisfy all subsequent data processing functions.

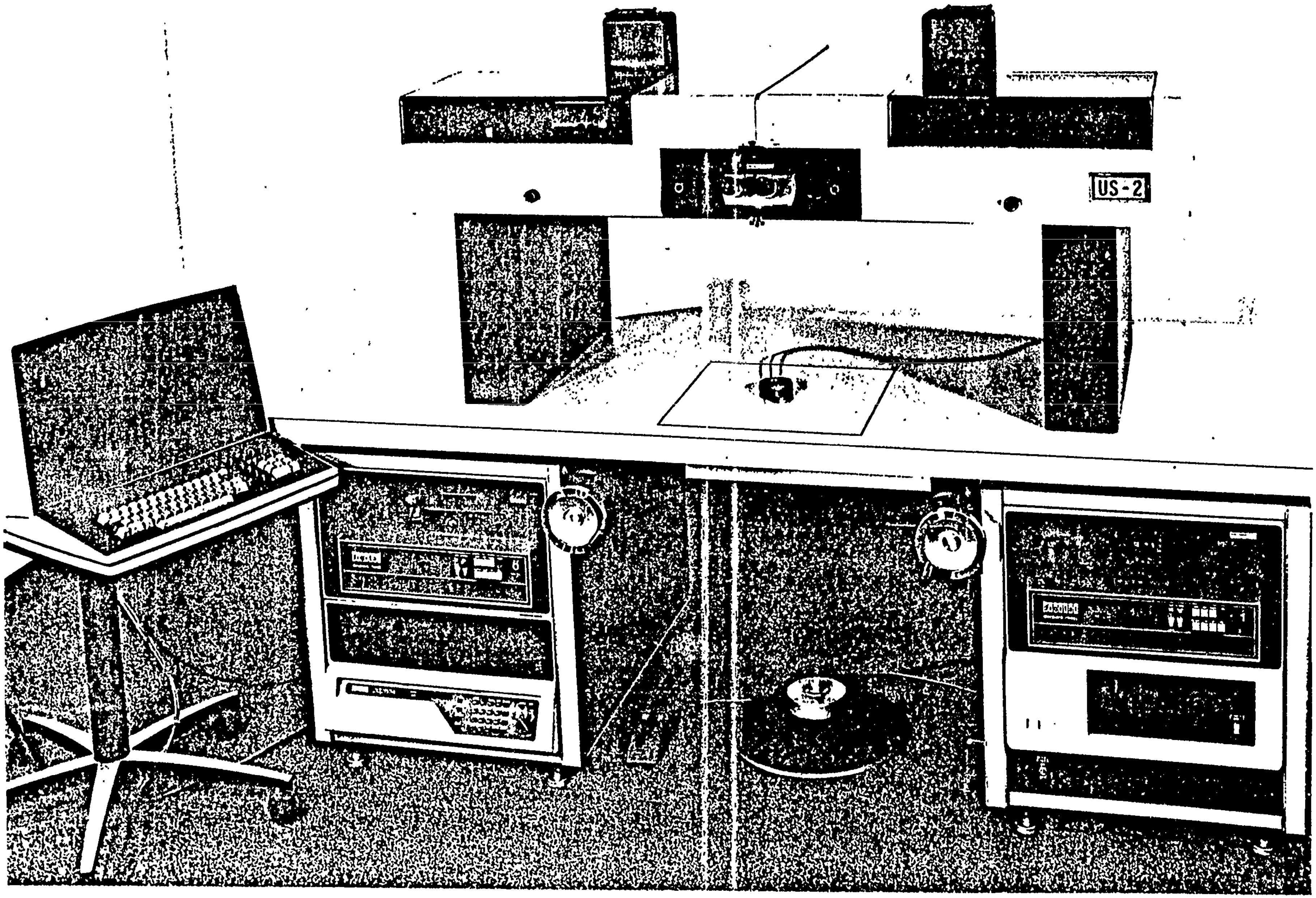


FIGURE E.13: A Computer-Controlled Stereoplotter. A mini-computer (set within legs of the instrument) numerically handles functions performed by mechanical solutions of the analogue variety of stereoplotters. Data are recorded on the computer's discs. The particular instrument shown is the US2; photograph courtesy of Helava Associates, Inc.

GENERATING NEW SHIP LINES FROM A PARENT HULL USING SECTION AREA CURVE VARIATION

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1. ABSTRACT

Section area curve variation may be used to obtain a new set of fair ship lines from a parent hull by varying any or all of the following parameters: prismatic coefficient, longitudinal center of buoyancy, extent of parallel midbody, or slopes at entrance and run. A standard series may be obtained by varying any one of these parameters independently while holding the other parameters constant. Deriving a new set of ship lines using this approach has an advantage over other methods since a known parent hull with good stability, resistance, seakeeping, etc, qualities may be selected as the starting point for the new design.

In this paper a linear system of 10 simultaneous equations is presented which allows the independent variation of three of the parameters: prismatic coefficient, longitudinal center of buoyancy, and extent of parallel midbody on a parent section area curve. Another linear system of 12 simultaneous equations is presented which allows the independent variation of the above three parameters and the slopes at the entrance and run of a parent section area surve. A new set of ship lines can be obtained directly from the new section area curve. Matrix methods are used to solve the systems of equations. Several examples with numeric and graphic results from a computer program developed at the Maritime Administration are presented.

2. INTRODUCTION

There are several methods used today for creation of ship lines by computer. For example, ship lines can be derived from one of the following:

a) a single parent hull (lines distortion approach)
b) a series of parent hulls (standard series approach)
c) geometrical hull form parameters (form parameter approach)

In the lines distortion approach new lines are obtained from the lines of one parent hull by modifying some form parameters, e.g. prismatic coefficient, longitudinal center of buoyancy, parallel midbody, etc. The advantage here is that known parent hull with good stability, resistance, and seakeeping qualities may be selected as the starting point for the new design. Lackenby [1]* developed a systematic mathematical approach to lines distortion of section area curves. Soding [2] developed transformation functions to distort section area curves, bilge radii, u-or-v shapes, stem and stern contours, etc.

Using the standard series approach, the derived hull form can be obtained by simply interpolating within the designs of that series. It is interesting to note that a standard series can be derived from a single parent or several parent designs by systematic variation methods such as lines distortion. (For example, the hulls of the British BSRA series were generated from several parent hulls using the lines distortion approach.developed in [1].) The parent designs and the deduced variations are model tested and then documented with the published standard series in terms of offsets, lines, curves of form, and resistance and propulsive data. Some of the standard series are: Japanese, British, and Swedish tanker and cargo series, German HSVA series, Taylor series, Series 60.

* Numbers in brackets designate References at end of paper.

In contrast to the lines distortion approach and the standard series approach, the form parameter approach does not require parent hulls. The new lines are created mathematically according to specified values of the parameters that define the significant curves of the new hull form. Of the three approaches, the form parameter approach allows the greatest range of form variation and consequently requires a very experienced designer. Further discussion of use of form parameters can be found in the paper by Nowacki [3J.

Depending on which approach is used to generate the derived hull form, the resistance will be known to varying degrees. In the standard series approach, resistance information can be interpolated from the tabulated series resistance data, so the resistance of the derived hull is known. In the lines distortion approach, the resistance of the parent is known, so that of the derived hull can be expected to be very similar since only moderate modifications to the parent are allowed with this method. (It should be noted that while the resistance will be similar, there is no guarantee that the new hull will produce <u>better</u> hydrodynamic behavior than the parent.) In the form parameter approach the resistance is not known.

The following presentation is concerned only with the lines distortion approach. In particular, the section area curve variation method developed in reference [l] is modified and extended. The objective is to systematically distort the section area curve of the parent hull using a mathematical approach such that the new section area curve - and therefore the new hull form - will have the desired characteristics.

3. THE LINES DISTORTION APPROACH- SECTION AREA CURVE VARIATION

Several authors have addressed section area curve variation, but one of the most complete papers was presented in 1950 by Lackenby [l]. He derived the equations for the independent variation of three parameters of the section area curve: prismatic coefficient (C_P), longitudinal center of buoyance (LCB), and extent of parallel midbody. Any or all of the three parameters could be varied independently holding the other parameters constant. For example, LCB could be varied holding CP and extent of parallel midbody constant. This represented a significant improvement over such traditional methods as "swinging" the section area curve to shift the LCB. With the traditional methods, there is no control over the position of parallel midbody or position of maximum section; they are shifted forward or aft with the new LCB. Additionally, the prismatic coefficient is changed slightly.

To develop the equations for section area curve variation, a figure with some definitions will prove useful. If areas of transverse sections at stations along the length of the ship are calculated up to the design waterline and then plotted, the resulting curve is called the section area curve. See Figure 1. It has the following properties:

a) The area under the curve is-equal to the underwater volume, ^{v}, of the ship at the.design waterline, DWL.
b) The first moment of the area is equal to the longitudinal center of buoyancy, LCB.
c) The non-dimensionalīred area under the curve is the prismatic. coefficient. Alternately, the maximum section area, A_M, when multiplied by the ship length, ^{L}SAC, gives a prison volume; this volume divided into the actual ship volume, y , is the prismatic coefficient, Cp.

Ship Profile

T = draft
DWL = design waterline
⊠ = midships
FP = forward perpendicular
AP = aft perpendicular

Section Area Curve

$A_S(x)$ = curve of section area below DWL vs length
A_M = maximum section area or area of midship section
L_F = length of forebody
L_A = length of aftbody
L_{SAC} = length of section area curve
= $L_F + L_A$
X_{LCB} = longitudinal center of buoyance
X_F = abscissa of centroid of forebody
X_A = abscissa of centroid of aftbody
∇_F = underwater volume of forebody
∇_A = underwater volume of aftbody
∇ = total underwater volume
= $\nabla_F + \nabla_A$
θ_{PF} = angle of entrance
θ_{PA} = angle of run

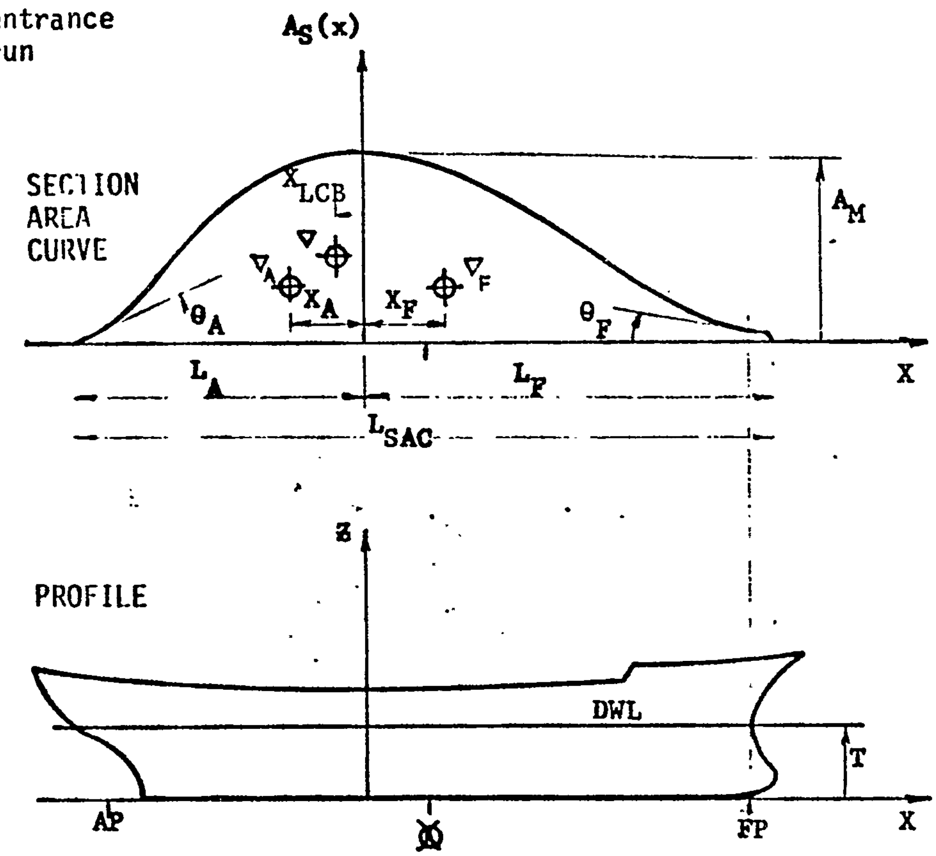

FIGURE 1. Section Area Curve Without Parallel Midbody

Note that the equations for section area curve variation apply equally well to waterlines. Only the terminology changes:

	Section Area Curve	Waterlines
Areas ;	underwater volume, V	waterplane area
Moments :	longitudinal center of buoyancy, LCB	longitudinal center of flotation, LCF
Non-dimensional areas:	prismatic coefficient, C_p	waterplane coefficient

The system of equations developed in [1] have three important limitations. The first being that length of forebody must be the same as length of aftbody. This is a result of the assumptions that the boundary between forebody and aftbody is exactly midships and that the stations forward of the forward perpendicular could be neglected. See Figure 2.

These assumptions cannot be made with the bulbous bows of today where the bulb volume is a non-negligible quantity, and with high speed cargo ships which have no parallel midbody and the station of maximum area is aft of midships. So the equations are rederived for a dimensional section area curve where length of forebody and aftbody may differ (as in Figure 1.).

The second limitation is that the original system of equations was solved by successive substitution. This obscures the presentation and makes the addition of new boundary conditions extremely difficult. A more general approach is to formulate the equations in matrices and use a direct numerical method like Gaussian elimination for the solution. A matrix approach greatly facilitates including additional boundary conditions in the system of equations, as will be done in what follows.

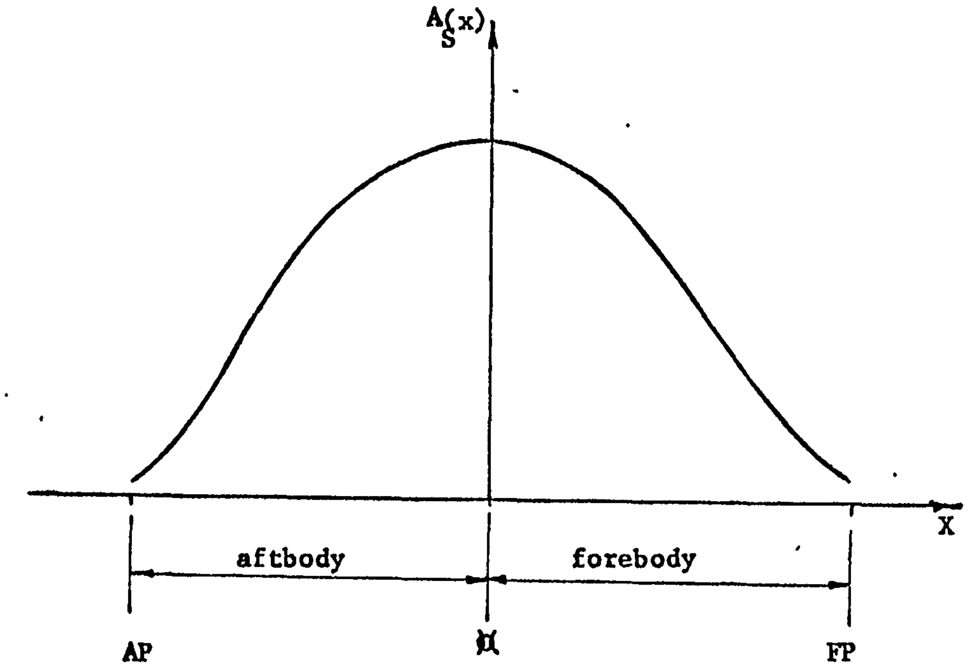

FIGURE 2. Section Area Curve with Equal Forebody and Aftbody Lengths

A third limitation is that the equation for the longitudinal shifts of stations on the parent section area curve is not in general form. The equation for longitudinal shifts of stations determines how the original stations on the parent section area curveare shifted longitudinally to produce the derived section area curve with the desired characteristics. When the equation for longitudinal shifts has been calculated, the original offset stations are also shifted according to that equation to produce the new offset stations; the heights and half-breadths remain constant and only the stations are changed. The 8x value a point on the parent section area curve is shifted longitudinally is plotted vertically in the curve of longitudinal shifts in Figure 3.

In this paper the curves of longitudinal shifts of stations are second or third order equations.1 There is one equation for the longitudinal shifts in the forebody and another equation for longitudinal shifts in the aftbody. Note in the example in Figure 3 that forebody stations on the parent section area curve are shifts forward (positive shifts) while aftbody stations on the parent section area curve are shifted forward (negative shifts).

As mentioned previously, the equation for longitudinal shifts of stations determines how the original stations on the parent section area curve are shifted longitudinally to produce a derived section area curve with the desired characteristics. So the objective is to calculate the coefficients of the equation for longitudinal shifts in the forebody and aftbody, We shall now present two systems of equations whose solutions are the coefficients of the equations of the longitudinal shifts. The first system of 10 linear simultaneous

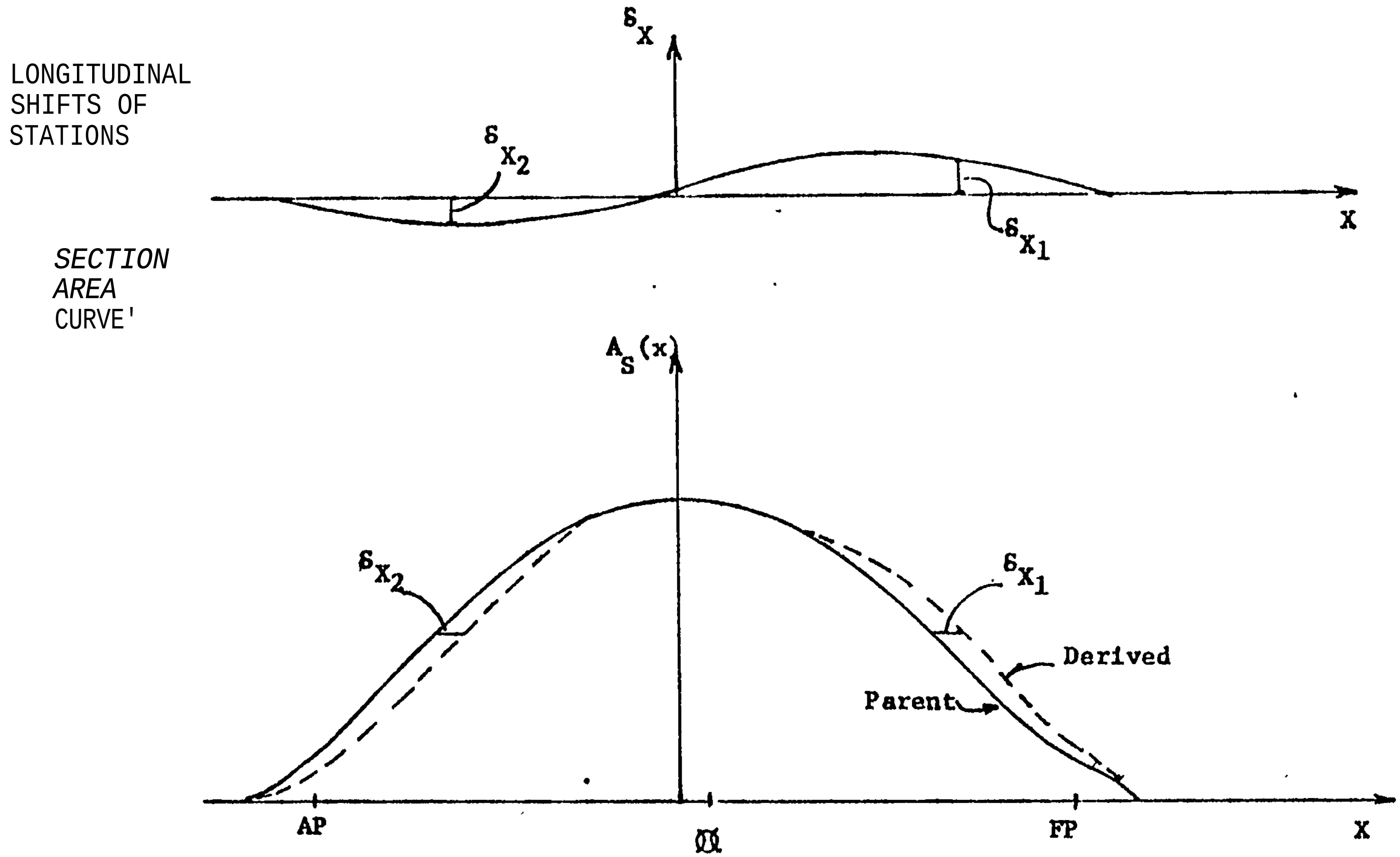

FIGURE 3. Longitudinal Shifts of Stations with Corresponding Derived Section Area Curve

equations allows the independent variation of three section area curve parameters: prismatic coefficient, longitudinal center of buoyancy, and extent of parallel midbody. In this case the equations of longitudinal shifts of stations are second order or parabolic. This is essentially the system of equations in [1] but with modifications to overcome the three mentioned limitations. The second system of 12 linear simultaneous equations allows the independent variation of prismatic coefficient, longitudinal center of buoyancy, extent of parallel midbody, and the slopes at the entrance and run. This is an extension of the system of 10 equations. Here the equations of longitudinal shifts of stations are third order or cubic.

4. EQUATIONS FOR PARABOLIC LONGITUDINAL SHIFTS

Four equations result from considering the forebody, four equations for the aftbody, and two equations for the combined forebody and aftbody; hence a system of ten linear simultaneous equations. The equations for the aftbody are identical in form to the four equations for the forebody, but the unknown coefficients are different and the X axis is reversed. The lengths of forebody and aftbody are not restricted to being equal.

4a. FOREBODY ONLY

In Figure 4 the solid curve abc represents the forebody of the parent section area curve. The x-axis units are length and the y-axis units are area. The dashed curve ab'c represents the forebody of the derived section area curve. At a position x the parent curve abc is shifted longitudinally by an amount 8x to produce curve ab'c.

Parent Forebody Curve (abc)

∇_F = underwater volume of forebody
x_F = abscissa of centroid of ∇_F
P_F = length of parallel midbody
L_F = length of forebody
A_M = maximum section area
x = abscissa of a point on abc
$A_s(x)$ = ordinate corresponding to x
θ_{PF} = slope of entrance of parent forebody

Derived Forebody Curve (ab'c)

$\delta\nabla_F$ = change in volume
$x_{\delta F}$ = abscissa of centroid of $\delta\nabla_F$
δP_F = change in parallel midbody
δx = longitudinal shift of station at x
θ_{DF} = slope of entrance of derived forebody

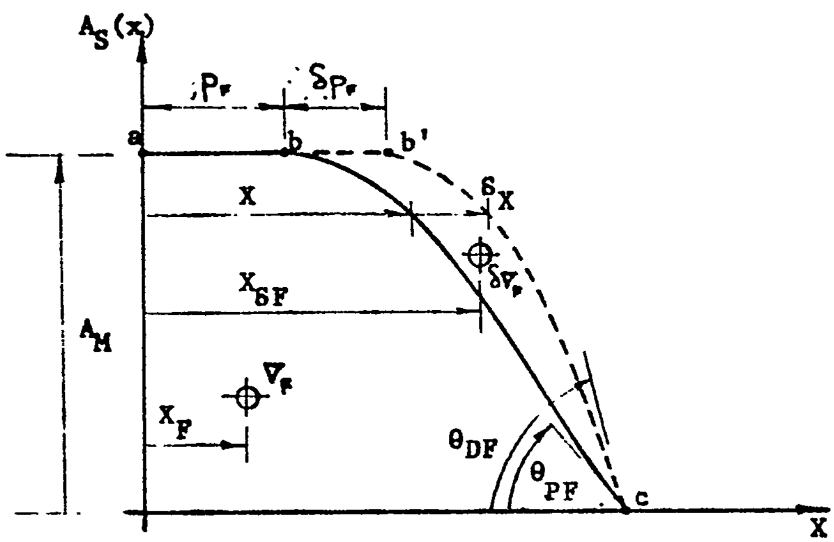

FIGURE 4. Forebody Section Area Curve

In order for the derived section area curve to have the desired prismatic coefficient, longitudinal center of buoyancy, and extent of parallel midbody, a second order expression of the following form is used for the longitudinal shifts in [l]:

(1) $8x = A(l-x)\ (x+B)$

where 8x is the necessary longitudinal shift at each position x along the forebody and A and B are coefficients to be determined from the boundary conditions. Note that the term (l-x) includes the boundary condition that 8x be zero at the forward end of the curve i,e., at x=1 for a non-dimensionalized forebody length.

Instead of equation (1) we shall use a more general second order expression to simplify the algebra:

(2) $8\,x = Ax^2 + Bx + c$

where A, B, and C are constants to be determined from the boundary conditions.

Four equations for the forebody result from the following conditions:

(3) at $x = P_F$, $8x = 8_{pF}$ $\qquad 8X = 8_{pF} = A_{pF}^2 + B_{pF} + C$

(4) at $x = L_F$' $8x = 0$ $\qquad 8X = 0 = AL_F^2 + BL_F + C$

(5) $\delta\nabla_F = \int_0^{A_M} \delta x dA_S$ $\qquad \delta\nabla_F = 2A\nabla_F x_F + B\nabla_F + CA_M$

(6) $X_{\delta F}\delta\nabla_F = \int_0^{A_M} x\delta x dA_c$ $\qquad X_{\delta F}\delta\nabla_F = 3A\nabla_F K^2_F + 2B\nabla_F x_F + C\nabla_F$

where in equation (6) K_F is the radius of gyration about the A_S axis. There are five unknowns: A, B, C, $\delta\nabla_F$, and $X_{\delta F}$. All other quantities can be determined from the geometry of the forebody.

For the aftbody there are four more equations similar to (3), (4), (5), and (6) but with the coefficients A, B, C changed to D, E, F, respectively, and with subscript F replaced by A. In this case the five unknowns are D, E, F, $\delta\nabla_A$, and $X_{\delta A}$.

4b. COMBINED FOREBODY AND AFTBODY

The total section area curve will now be considered to develop the remaining two equations. Figure 5 shows the total section area curve with the various parameters labeled. The solid curve is the parent and the dashed curve is the derived.

Two equations for the total section area curve result from the following conditions:

(7) $$(\nabla + \delta\nabla)(X_{LCB} + \delta X_{LCB}) = \nabla X_{LCB} + \delta\nabla_F X_{\delta F} - \delta\nabla_A X_{\delta A}$$

The total change must equal the change forward plus the change aft.

(8) $$\delta\nabla = \delta\nabla_F + \delta\nabla_A$$

With equations (3), (4), (5), (6) for the forebody and four more equations similar to (3), (4), (5), (6) for the aftbody, and equations (7) and (8) for the total section area curve, we have a system of ten equations in ten unknowns. The equations are written in matrix form in Figure 6. The ten unknowns are contained in the column vector at the right. The matrix and the column vector at the left contain all known quantities. A direct numerical method like Gaussian elimination can be used for the solution. Once the coefficients A, B, C and D, E, F are calculated, the longitudinal shifts in the forebody are known

Parent Section Area Curve

∇ = underwater volume

= ∇ + v

x_{LCB} = longitudinal center of buoyance

P_F = length of parallel midbody in forebody

PA = length of parallel midbody In aftbody

θ_{PF} = slope of entrance of parent forebody

θ_{PA} = slope of run of parent aftbody

Derived Section Area Curve

$\delta\nabla$ = change in underwater volume

= $\delta\nabla + \delta\nabla$

$\delta\nabla_F$ = change in volume of forebody

$\delta\nabla_A$ = change in volume of aftbody

δx_{LCB} = change in longitudinal center of buoyancy

δ_{PF} = change in parallel midbody in forebody

δ_{PA} = change in parallel midbody in aftbody

θ_{DF} = slope of entrance of derived forebody

θ_{DA} = slope of run of derived aftbody

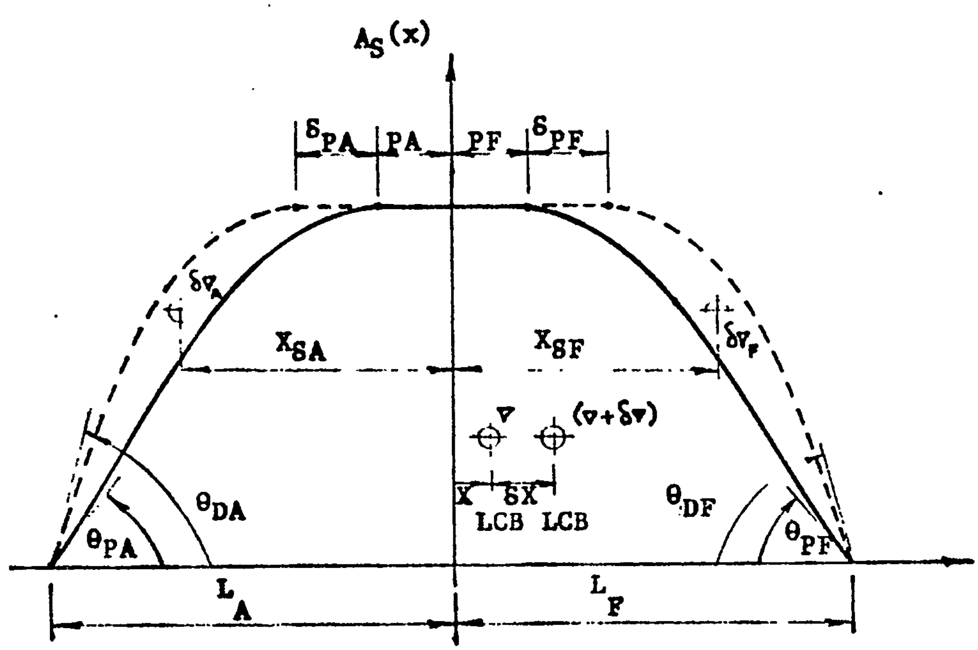

FIGURE 5. Total Section Area Curve

$$
\begin{Bmatrix} \delta p_F \\ 0 \\ 0 \\ 0 \\ \delta p_A \\ 0 \\ 0 \\ 0 \\ \delta\nabla \\ (\nabla+\delta\nabla)(x_{LCB}+\delta x_{LCB})-\nabla x_{LCB} \end{Bmatrix}
=
\begin{bmatrix}
p_F^2 & p_F & 1 & & & & & & & \\
L_F^2 & L_F & 1 & & & & & & & \\
2\nabla_F x_F & \nabla_F & A_M & -1 & & & & & & \\
3\nabla_F K_F^2 & 2\nabla_F x_F & \nabla_F & & -1 & & & & & \\
 & & & & & p_A^2 & p_A & 1 & & \\
 & & & & & L_A^2 & L_A & 1 & & \\
 & & & & & 2\nabla_A x_A & \nabla_A & A_M & -1 & \\
 & & & & & 3\nabla_A K_A^2 & 2\nabla_A x_A & \nabla_A & & -1 \\
 & & & 1 & & & & & 1 & \\
 & & & & 1 & & & & & -1
\end{bmatrix}
\begin{Bmatrix} A \\ B \\ C \\ \delta\nabla_F \\ x_{\delta F}\delta\nabla_F \\ D \\ E \\ F \\ \delta\nabla_A \\ x_{\delta A}\delta\nabla_A \end{Bmatrix}
$$

FIGURE 6. Ten Linear Simultaneous Equations for Parabolic Longitudinal Shifts

$$(9) \quad \delta X_F = Ax^2 + Bx + C$$

and the longitudinal shifts in the aftbody are known

$$(10) \quad \delta X_X + Dx^2 + Ex + F$$

When points on the parent section area curve are shifted longitudinally according to equations (9) and (10), the resulting section area curve will have the derived prismatic coefficient, longitudinal center of buoyancy, and extent of parallel midbody. When stations in the offsets are shifted longitudinally according to equations (9) and (10), a derived hull form will result which has these characteristics.

5. EQUATIONS FOR CUBIC LONGITUDINAL SHIFTS

In this case five equations result from considering the forebody, five equations from the aftbody, and two equations from the combined forebody and aftbody; hence a system of twelve linear simultaneous equations. Again the aftbody and forebody equations are identical in form , but with different coefficients and different x-axis.

5a• FOREBODY ONLY

Figure 4 again applies, but the equation for longitudinal shifts becomes a third order expression.

$$(11) \quad \delta X = Ax^3 + Bx^2 + Cx + D$$

Where A, B, C, D, are constants to be determined from the boundary conditions.- The forth constant is required since there is an added boundary condition; the slope at the end of the curve is specified.

Five equations for the forebody result from the following conditions:

(12) at $x = L_F$, $\frac{dy}{dx}$ = specified value $\quad \tan\theta_{PF}\cot\theta_{DF} - 1 = 3AL_F^2 + 2BL_F + C$

(13) at $x = P_F$, $\delta x = \delta p_F$ $\quad \delta x = \delta p_F = Ap_F^3 + Bp_F^2 + Cp_F + D$

(14) at $x = L_F$, $\delta x = 0$ $\quad \delta x = 0 = AL_F^3 + BL_F^2 + CL_F + D$

(15) $\delta\nabla_F = \int_0^{A_M} \delta x dA_S$ $\quad \delta\nabla_F = 3A\nabla_F k_F^2 + 2B\nabla_F x_F + C\nabla_F + DA_M$

(16) $X_{\delta F}\,\delta\nabla_F = \int_0^{A_M} x\delta x dA_S$ $\quad X_{\delta F}\delta\nabla_F = 4A\nabla_F R_F^3 + 3B\nabla_F K_F^2 + 2C\nabla_F X_F + D\nabla_F$

where in equation (12) $\tan\theta_{PF}$ is the slope of the parent curve at $X = L_F$ (which is known) and $\cot g_{DF}$ is the inverse of the slope of the derived curve at $X=L_F$ (which is specified) and where in equations (15) and (16) K_F is the radius of gyration (or lever of the second moment) about the A_S axis and in equation (16) R_F is the lever of the third moment about the A_S axis. There are six unknowns: A, B, D, D, $\delta\nabla_F$, $X_{\delta F}$. All other quantities can be determined from the geometry of the forebody.

For the aftbody there are five more equations similar to (12), (13), (14), (15), (16), but with coefficients A, B, C, D changed to E, F, G, H respectively and subscript F replaced by A. There the six unknowns are E, F, G, H, $\delta\nabla_A$, X_{SA}.

5b. Combined Forebody and Aftbody

Figure 5 applies and the two equations for the total section area curve are again equations (7) and (8). With equations (12), (13), (14), (15), (16) for the forebody, five similar equations for the aftbody, and equations (7) and (8) for

the total section area curve, we have a system of twelve equations in twelve unknowns. These equations are written in matrix form in Figure 7. The twelve unknowns are contained in the column vector at the right. The matrix and the column vector at the left contain all known quantities. Using Gaussian elimination for the solution the coefficients A, B, C, D and E, F, G, H are calculated and so the longitudinal shifts in the forebody are:

$$(17) \quad \delta x_F = Ax^3 + Bx^2 + Cx + D$$

and the longitudinal shifts in the aftbody are

$$(18) \quad \delta x_A = Ex^3 + Fx^2 + Gx + H$$

When points on the parent section area curve are shifted longitudinally according to equations (17) and (18), the resulting section area curve will have the desired prismatic coefficient, longitudinal center of buoyancy, extent of parallel midbody, slope of entrance, and slope of run. When stations in the offsets are shifted longitudinally according to equations (17) and (18), a derived hull fon will result which has these characteristics. A new hull will have been generated from a parent hull using section area curve variation.

$$
\begin{Bmatrix}
\tan\Theta_{PF}\cot\Theta_{DF}-1 \\
\delta p_F \\
0 \\
0 \\
0 \\
\tan\Theta_{PA}\cot\Theta_{DA}-1 \\
\delta p_A \\
0 \\
0 \\
0 \\
\delta\nabla \\
(\nabla+\delta\nabla)(X_{LCB}+\delta X_{LCB})-\nabla X_{LCB}
\end{Bmatrix}
=
\begin{bmatrix}
3L_F^2 & 2L_F & 1 & & & & & & & & & \\
p_F^3 & p_F^2 & p_F & 1 & & & & & & & & \\
L_F^3 & L_F^2 & L_F & 1 & & & & & & & & \\
3\nabla_F K_F^2 & 2\nabla_F X_F & \nabla_F & & -1 & & & & & & & \\
4\nabla_F R_F^3 & 3\nabla_F K_F^2 & 2\nabla_F X_F & \nabla_F & & -1 & & & & & & \\
 & & & & & & 3L_A^2 & 2L_A & 1 & & & \\
 & & & & & & p_A^3 & p_A^2 & p_A & 1 & & \\
 & & & & & & L_A^3 & L_A^2 & L_A & 1 & & \\
 & & & & & & 3\nabla_A K_A^2 & 2\nabla_A X_A & \nabla_A & & -1 & \\
 & & & & & & 4\nabla_A R_A^3 & 3\nabla_A K_A^2 & 2\nabla_A X_A & \nabla_A & & -1 \\
 & & & & 1 & & & & & & 1 & \\
 & & & & & 1 & & & & & & -1
\end{bmatrix}
\begin{Bmatrix}
A \\ B \\ C \\ D \\ \delta\nabla_F \\ X_{SF}\delta\nabla_F \\ E \\ F \\ G \\ H \\ \delta\nabla_A \\ X_{SA}\delta\nabla_A
\end{Bmatrix}
$$

FIGURE 7. Twelve Linear Simultaneous Equations for Cubic Longitudinal Shifts

6. CONCLUSIONS

Some typical computer methods for generating new ship lines were first briefly discussed. Then the lines distortion approach of section area curve variation was presented in detail. A systematic mathematical approach to section area curve variation using matrices was developed which gives a closed form solution and simplifies changing the boundary conditions. The derivation of a system of twelve linear simultaneous equations for cubic longitudinal shifts demonstrates how two more boundary conditions are easily added to the original system of ten equations. Several examples with numeric and graphic results from a computer program developed at the Maritime Administration are presented. The graphic results demonstrate that the derived section area curves look reasonable and the numeric results show that the derived curve has the desired form parameters.

Development is underway to add calculations and plots of the non-dimensional curvature of both parent and derived section area curves to the computer program. This would show how section area curve variation affects the curvatures on the parent section area curve. Additionally, it would be interesting to see the results of using section area curve variation on a hull which was faired by a program like HULDEF, since the program has not been tested on a construction design. In any case the method presented should be adequate for generating new lines for preliminary design, with the restriction that changes be moderate, i.e., up to 10% change in prismatic coefficient and about 2% change in longitudinal center of buoyancy.

7. REFERENCES

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8. NUMERIC AND GRAPHIC RESULTS

a. Example 1 - parabolic longitudinal shifts
shift LCB forward, increase Cp

b. Example 2 - parabolic longitudinal shifts
shift LCB forward, increase Cp, add parallel midbody

c. Example 3 - parabolic longitudinal shifts
shift LCB aft, decrease Cp, set forebody/aftbody boundary

d. Example 4 - cubic longitudinal shifts
shift LCB aft, decrease Cp, set forebody/aftbody boundary

EXAMPLE 1

PARENT. NO PARALLEL MIDBODY,NO BULB
DERIVED. SHIFT LOB FORWARD INCREASE CP .

VALUE OF DETERMINANT
0.42210771E+23

	PARENT X	DELTA X	DERIVED X	AREA
1	0.0000	0.0000	0.0000	253.5500
2	14.0000	-3.5108	10.4892	301.5690
3	28.0000	-6.6800	21.3200	341.0370
4	42.0000	-9.5076	32.4924	405.4760
5	56.0000	-11.9937	44.0063	555.8600
6	84.0000	-15.9411	68.0589	947.1400
7	112.0000	-18.5221	93.4779	1387.9659
8	140.0000	-10.7368	120.2632	1819.8840
9	168.0000	-10.5852	148.4148	2194.8540
10	196,0000	-18. .0672	177.9328	2479.9971
11	224.0000	-15.1829	208.8171	2671.6680
12	252.0000	-10.9323	241.0677	2778.4651
13	280.0000	-5.3154	274.6846	2804.5161
14	301.7856	0.0000	301.7856	2811.3486
15	304.0000	0.3934	304.3934	2811.2581
16	336.0000	5.3191	341.3191	2756.2529
17	364.0000	8.4630	372.4630	2626.2661
18	392.0000	10.5188	402.5188	2418.4031
19	420.0000	11.4862	431.41362	2118.8689
20	448.0000	11.3655	459.3655	1728.0400
21	476.0000	10.1565	48.1565	1236.4340
22	504.0000	7.8592	511.8592	724.7050
23	532.0000	4.4737	536.4738	248.6890
24	560.0000	0.0000	560.0000	15.2270

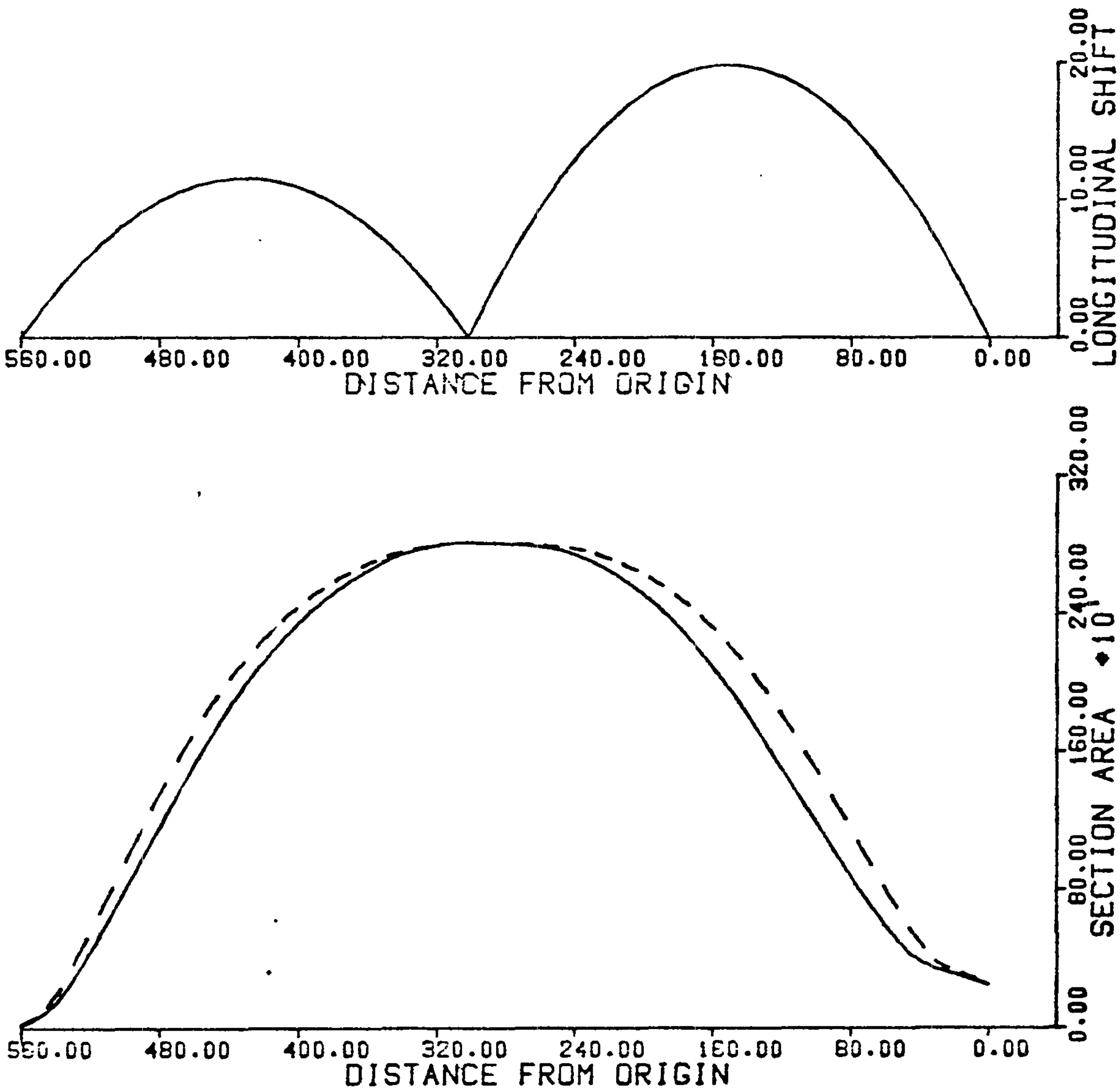
	DERIVED X	DELTA X	PARENT X	AREA
1	0.0000	0.0000	0.0000	253.5500
2	14.0000	4.7316	18.7316	315.2173
3	28.0000	8.5118	36.5118	372.8656
4	42.0000	11.5703	53.5703	524.5657
5	56.0000	14.1343	70.1343	747.3918
6	84.0000	17.5774	101.5774	1224.1975
7	112.0000	19.5896	131.5896	1690.9563
8	140.0000	20.0106	160.0106	2093.2683
9	168.0000	19.1748	187.1748	2396.9578
10	196.0000	17.3467	213.3467	2604.1907
11	224.0000	14.8907	238.8907	2735.2859

12	252.0000	7.9638	259.9638	2789.9961
13	280.0000	3.3310	283.3310	2806.1023
14	301.7856	0.0000	301.7856	2811.3486
15	304.0000	-1.2838	302.7162	2811.3223
16	336.0000	-3.7207	332.2793	2768.6643
17	364.0000	-7.9975	356.0025	2669.9341
18	392.0000	-10.0361	381.9639	2501.3291
19	420.0000	-11.2910	408.7040	2349.8271
20	448.0000	-11.7303	436.2697	1905.1338
21	476.0000	-10.9098	465.0902	1431.2815
22	504.0000	-8.5561	495.4439	881.1740
23	532.0000	-5.2440	526.7560	333,2687
24	560.0000	0.0000	560.0000	15.3270

DEPIVED SECTION AREA CURVE-DFSIRED VALUES	(PROGRAM INPUT)
PRISNATIC COFFFICIENT	0.6610
LOB (ABOUT ORIGIN)	283.0000
CHANGE IN PARALLEL MIDBODY IN FOREBODY	0.0000
CHANGE IN PARALLEL MIDBODY IN AFTBODY	0.0000

PARENT SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	TOTAL	
PRISMATIC COEFFICIENT	0.6189	
LOB (ABOUT ORIGIN)	285.2349	
MAXIMUM SECTION AREA	2911.3486	
X VALUE. WHERE SECTION AREA IS MAX	301.7856	
	FOREBODY	AFTRODY
PRISMATIC COEFFICIENT	0.6236	0.6133
X VALUE WHERE SA CURVE HAS ZERO SLOPE	301.7856	301.7856
LENGH OF PARALLEL MIDBODY	0.0000	0.0000
LOG (ABOUT X AT MAX SA)	105.6420	89.3171
RADIUS OF GYRATION (ABOUT X AT MAX SA)	126.9857	106.8458

DERIVED SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	FOREBODY	AFTBODY
CHANGE IN PRISMATIC COEFFICIENT	0.0492	0.0339
LOG OF CHANGE IN CP (ABOUT X AT MAX SA)	170.0123	149.2565
	TOTAL (ON UNEVEN SPACING)	
PRISMATIC COEFFICIENT	.0.6610	
PEPCENT CP ERROR (ACTUAL VS DESIRED)	0.0013	
LOB (ABOUT ORIGIN)	282.7675	
PERCENT LOB ERROR (ACTUAL VS DESIRED)	-0.0822	
	TOTAL (ON EVEN SPACING)	
PRISMATIC COEFFICIENT	0.6612	
PERCENT CP ERROR (ACTUAL VS DESIRED)	0.0324	
LOP (ABOUT ORIGIN)	282.8586	
PERCENT LOB ERROR (ACTUAL VS DESIRED)	-0.0500	



PARENT. NO PARALLEL MIDBODY, NO BULB
DERIVED. SHIFT LCB FORWARD, INCREASE CP

EXAMPLE 2

PARENT. N0 PARALLEL MIDBODY, AXIS AT FP
DERIVED. SHIFT LCB FWD, INCREASE CP, ADD PARALLEL MIDBODY

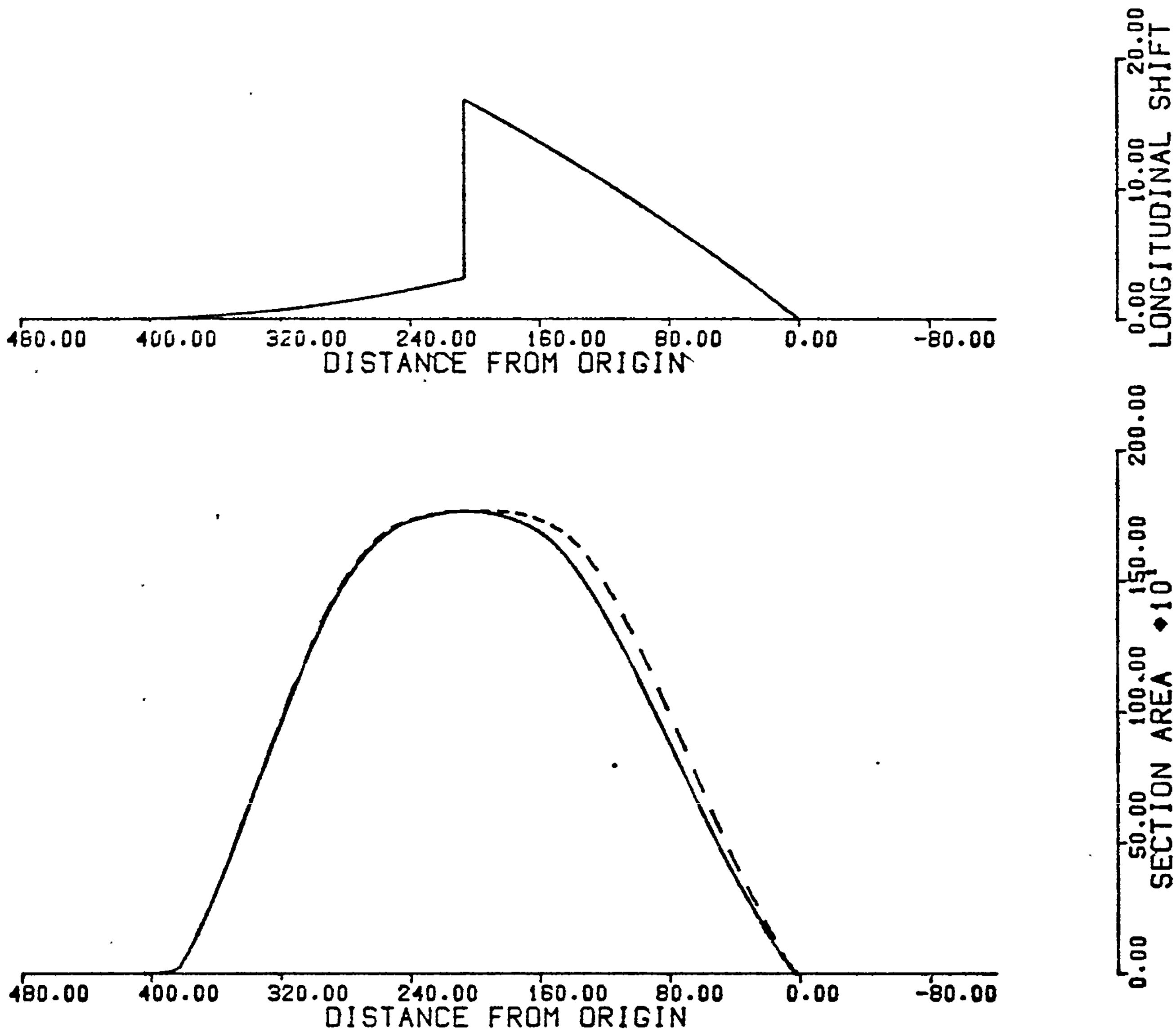
VALUE OF DF DETERMINANT
0.19152752E+22

	PAPENT X	DELTA X	DERIVED X	AREA
1	0.0000	0.0000	0.0000	0.0000
2	5.0000	-0.4833	4.5167	15.7600
3	10.0900	-0.9628.	9.0372	55.9200
4	15.0000	-1.4386	13.5614	104.7000
5	20.0000	-1.9106	18.0894	155.8200
6	30.0000	-2.8434	27.1566	260.0600
7	40.0000	-3.7611	36.2389	370.3000
8	50.0000	-4.6639	45.3361	489.2900
9	60.0000	-5.5517	54.4493	615.3700
10	80.0000	-7.2823	72.7177	877.4300
11	100.0000	-8.9529	91.0471	1135.4000
12	120.0000	-10.5635	109.4365	136R.1100
13	160.0000	-13.6047	146.3953	1685.9200
14	200.0000	-16.4059	183.5941	1764.9100
15	206.6624	-16.8624	190.0000	1766.2482
16	206.8624	3.1376	210.0000	1766.2482
17	240.0000	2.2524	242.2534	1728.4100
18	280.0000	1.3765	281.3765	1497.5699
19	300.0000	1.0175	301.0175	1257.3700
20	320.0000	0.7113	320.7113	959.1800
21	339.0000	0.5779	330.5779	796.7300
22	340.0000	0.4577	340.4577	630.0800
23	350.0000	0.3507	350.3506	464.8100
24	360.0000	0.2568	360.2568	309.1600
25	370.0000	0.1761	370.1761	168.3500
26	375.0000	0.1407	375.1407	104.7400
27	380.0000	0.1086	380.1086	44.4800
28	390.0000	0.0542	390.0542	3.7900
29	395.0000	0.0320	395.0320	1.0600
30	400.0000	0.0130	400.0131	0.2100
31	404.0900	0.0000	404.0900	0.0400

DEPINED SECTION AREA CURVE-DESIRED VALUES	(PROGRAM INPUT
PRISMATIC COEFFICIENT	0.6120
LCB (ABOUT ORIGIN)	l98.0600
CHANGE IN PARALLEL MIDBODY IN FOREBODY	16.8624
CHANGE TN PARALLEL MIDBODY TN AFTBODY	3.1376

PARENT SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	-TOTAL	
PRISMATIC COEFFlCIENT	0.5919	
LCB (ABOUT ORIGIN)	200.5799	
MAXIMUM SECTION AREA	1766.2482	
X VALUE WHERE SECTION APEA IS MAX	206.8624	
	FORE BODY	AFIBODY
PRISMATIC COEFFICIENT	0.6024	0.5810
X VALUE WHERE SA CURVE HAS ZERO SLOPE	206.8624	206.8624
LENGTH OF PARALLEL MIDBODY	0.0000	0.0000
LCG (ABOUT X AT MAX SA)	70.3265	63.3594
RADIUS OF GYRATION (ABOUT X AT MAX SA)	84.5154	75.8073

DERIVED SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	FOREBODY	AFTBODY
CHANGE IN PRISMATIC COEFFICIENT	0.0354	0.0040
LCG OF CHANGE IN CP (ABOUT X AT MAX SA)	101.6077	85.4954
	TOTAL (ON UNEVEN SPACING)	
PRISMATIC COEFFICIENT	0.6120	
PERCENT CP ERROR (ACTUAL VS DESIRED)	0.0011	
LCB (ABOUT ORIGIN)	197.8740	
PERCENT LCB ERROR (ACTUAL VS DESIRED1	-0.0940	
	TOTAL (ON EVEN SPACING)	
PRISMATIC COEFFICIENT	0.6117	
PERCENT CP ERROR (ACTUAL VS DESIRED)	-0.0443	
LCB (ABOUT ORIGIN)	197.6116	
PERCENT LCB ERROR (ACTUAL VS DESIRED)	-0.2269	



PARENT. NO PARALLEL MIDBODY, Y AXIS AT FP
DERIVED. SHIFT LCB FWD, INCREASE CP, ADD PARALLEL MIDBODY

EXAMPLE 3

PARENT. WITH PARALLEL MIDBODY
DERIVED. SHIFT LCB AFT, DECREASE CP, SET F/A BOUNDARY

VALUE OF DETERMINANT
0.17685459E+04

	PARENT X	DELTA X	DERIVED X	AREA
1	0.0000	0.0000	0.0000	0.0000
2	0.2500	0.0391	0.2891	0.0510
3	0.5000	0.0729	0.5729	0.1410
4	0.7500	0.1016	0.8516	0.2580
5	1.0000	0.1251	1.1351	0.3810
6	1.5000	0.1563	1.6563	0.6230
7	2.0060	0.1667	2.1667	0.8190
8	2.5000	0.1563	2.6563	0.9440
9	3.0000	0.1251	3.1251	0.9880
10	4.0000	-0.0000	4.0000	1.0000
11	4.2000	0.0000	4.2000	1.0000
12	5.0000	0.0000	5.0000	1.0000
13	6.0000	-0.0261	5.9739	0.9990
14	7.0000	-0.0391	6.9609	0.9210
15	7.5000	-0.0407	7.4593	0.8260
16	8.0000	-0.0301	7.9609	0.6880
17	8.5000	-0.0342	8.4658	0.5100
18	9.0000	-0.0261	8.9739	0.3280
19	9.2500	-0.0208	9.2292	0.2360
20	9.5000	-0.0147	9.4853	0.1510
21	9.7500	-0.0077	9.7423	0.0690
22	10.0000	0.0000	10.0000	0.0150

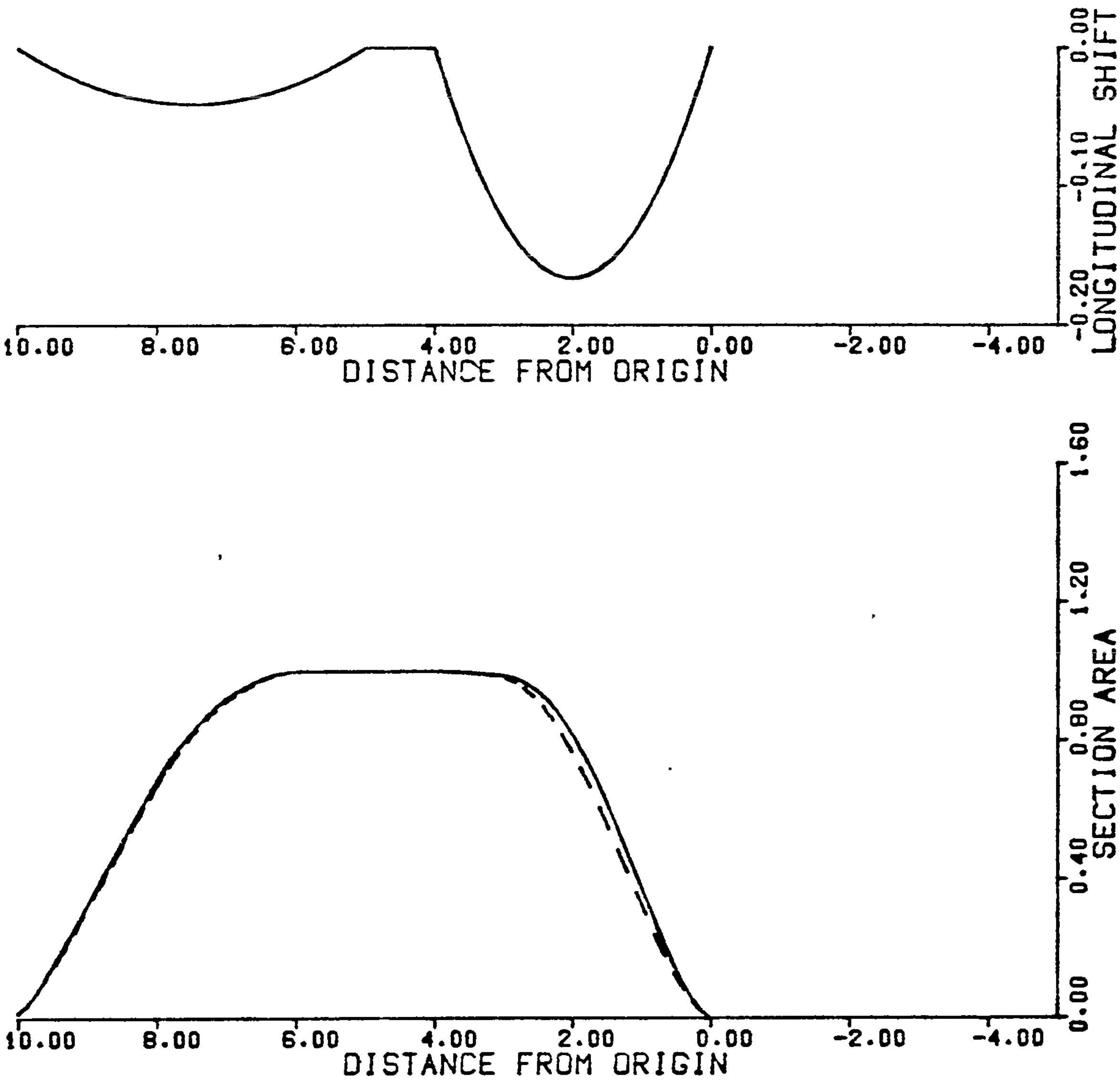
	DERIVED X	DELTA X	PARENT X	AREA
1	0.0000	0.0000	0.0000	0.0000
2	0.2500	-0.0351	0.2149	0.0414
3	0.5000	-0.0651	0.4349	0.1136
4	0.7500	-0.0925	0.6575	0.2137
5	1.0000	-0.1146	0.8854	0.3246
6	1.5000	-0.1477	1.3523	0.5519
7	2.0000	-0.1577	1.8423	0.7605
8	2.5000	-0.1285	2.3715	0.9143
9	3.0000	-0.0909	2.9091	0.9827
10	4.0000	0.0000	4.0000	1.0000

11	4.2000	0.0000	4.2000	1.0000
12	5.0000	0.0000	5.0001)	1.0000
13	6.0000	0.0023	6.0023	9.9989
14	7.0000	0.0288	7.0288	0.9156
15	7.5000	0.0373	7.5373	0.8162
16	8.0000	0.0386	8.0386	0.6744
17	8.5000	0.0337	8.5337	0.4978
18	9.0000	0.0256	9.0256	0.3186
19	9.2500	0.0205	9.2705	0.2287
20	9.5000	0.0143	9.5143	0.1462
21	9.7500	0.0076	9.7576	0.0667
22	10.0000	0.0000	10.0000	0.0150

DERIVED SECTION AREA CURVE-DESIRED VALUES	(PROGRAM INPUT)
PRISMATIC COEFFICIENT	0.7000
LCB (ABOUT ORIGIN)	4.9500
CHANGE IN PARALLEL MIDBODY TN FOREBODY	0.0000
CHANGE IN PARALLEL MIDBODY IN AFTBODY	0.0000

PARENT SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	TOTAL	
PRISMATIC COEFFICIENT	0.7154	
LCB (ABOUT ORIGIN)	4.9027	
MAXIMUM SECTION AREA	1.0000	
X VALUE WHERE SECTION AREA IS MAX	4.2000	
	FOREBODY	AFTBODY
PRISMATIC COEFFICIENT	0.6902	0.7337
X VALUE WHERE SA CURVE HAS ZERO SLOPE	4.0000	5.0000
LENGTH OF PARALLEL MIDBODY	0.2000	9.8000
LCG (ABOUT X AT MAX SA)	1.5381	2.2292
RADIUS OF GYBATION (ABOUT X AT MAX SA)	1.8176	2.6257

DERIVED SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	FOREBODY	AFTBODY
CHANGE TN PRISMATIC COEFFICIENT	-0.0298	-0.0050)
LCG OF CHANGE IN CP (ABOUT X AT MAX SA)	2.6916	3.9028
	TOTAL (ON UNEVEN SPACING)	
PRISMATIC COEFFICIENT	0.7000	
PERCENT CP ERROR (ACTUAL VS DESIRED)	0.0024	
LCB (ABOUT ORIGIN)	4.9492	
PERCENT LCB ERROR (ACTUAL VS DESIRED)	-0.0155	
	TOTAL (0N EVEN SPACING)	
PRISMATIC COEFFICIENT	0.7000	
PERCENT CP ERROR (ACTUAL VS DESIRED)	0.0046	
LCB (ABOUT ORIGIN)	4.9495	
PERCENT LCB ERROR (ACTUAL VS DESIRED)	-0.0110	



PARENT. WITH PARALLEL MIDBODY
DERIVED. SHIFT LCB AFT.DECREASE CP.SET F/A BOUNDARY

EXAMPLE 4

PARENT. WITH PARALLEL MIDBODY
DERIVED. SHIFT LCB AFT, DECREASE CP, SET F/A BOUNDARY

I

VALUE OF DETERMINANT
0.17685459E+04

	PARENT X	DELTA X	DERIVED X	AREA
1	0.0000	0.0000	0.0000	0.0000
2	0.2500	0.0391	0.2891	0.0510
3	0.5000	0.0729	0.5729	0.1410
4	0.7500	0.1016	0.8516	0.2580
5	1.0000	0.1251	1.1251	0.3810
6	1.5000	0.1563	1.6563	0.6230
7	2.0000	0.1667	2.1667	0.8190
8	2.5000	0.1563	2.6563	0.9440
9	3.0000	0.1251	3.1251	0.9880
10	4.01300	-0.0000	4.0000	1.0000
11	4.2000	0.0000	4.2000	1.0000
12	5.0000	0.0000	5.0000	1.0000
13	6.0000	-0.0261	5.9739	0.9890
14	7.0000	-0.0391	6.9609	0.9210
15	7.5000	-0.0407	7.4593	0.8260
16	8.0000	-0.0391	7.9609	0.6880
I7	8.5000	-0.0342	8.4658	0.5100
18	9.0000	-0.0261	8.9739	0.3289
19	9.2500	-0.0208	9.2292	0.2360
20	9.5000	-0.0147	9.4853	0.1510
21	9.7500	-0.0077	9.7423	0.0690
22	10.0000	0.0000	10.0000	0.0150

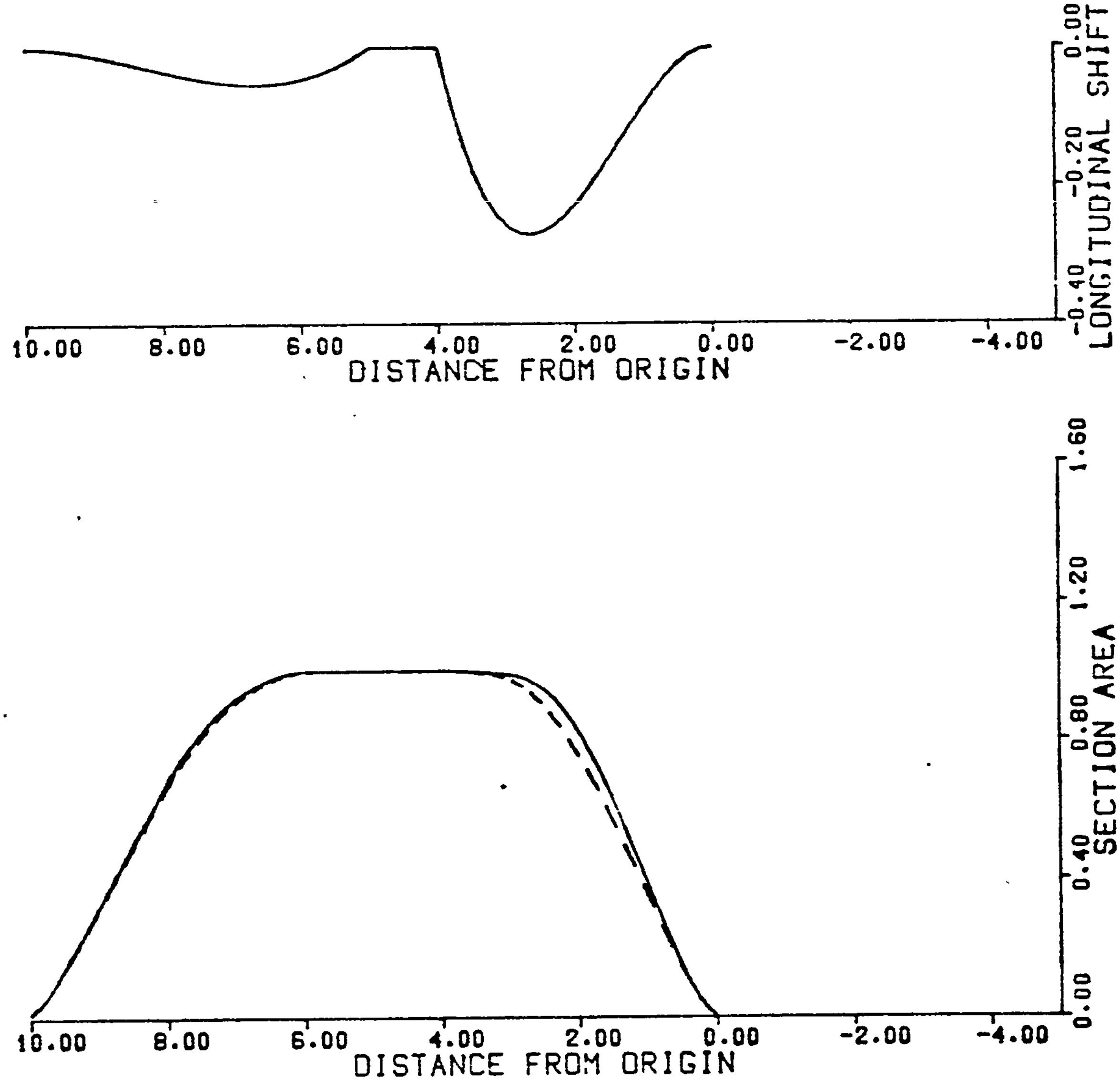
	DERIVED X	DELTA X	PARENT X .	AREA
1	0.0000	0.0000	0.0000	0.0000
2	0.2500	-.0351	0.2149	0.0414
3	0.5000	-0.0651	0.4349	0.1136
4	0.7500	-0.0925	0.6575	0.2137
5	1.0000	-0.1146	O.8854	0.3246
6	1.5000	-0.1477	1.3523	0.5519
7	2.0000	-0.1577	1.8423	0.7605
8	2.5000	-0.1285	2.3715	0.9143
9	3.0000	-0.0909	2.9091	0.9827
10	4.0000	0.0000	4.0000	1.0000
11	4.2000	0.0000	4.2000	l.0000

12	5.0000	0.00000	5.0000	1.0000
13	6.0000	0.0023	6.0023	0.9989
14	7.0000	0.0288	7.0288	0.9156
15	7.5000	0.0373	7.5373	0.8162
16	8.0000	0.0386	8.0386	0.6744
17	8.5000	0.0337	8.5337	0.4978
18	9.0000	0.0256	9.0256	0.3186
19	9.2500	0.0205	9.2705	0.2287
20	9.5000	0.0143	9.5143	0.1462
21	9.7500	0.0076	9.7576	0.0667
22	10.0000	0.0000	10.0000	0.0150

DERIVED SECTION AREA CURVE-DESIRED VALUES	(PROGRAM INPUT)
PRISMATIC COEFFICIENT	0.7000
LCB (ABOUT ORIGIN)	4.0500
CHANGE IN PARALLEL MIDBODY IN FOREBODY	0.0000
CHANGE IN PARALLEL MIDBODY IN AFTBODY	0.0000

PARENT SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	TOTAL	
PRISMATIC COEFFICIENT	0.7154	
LCB (ABOUT ORIGIN)	4.9027	
MAXIMUM SECTION AREA	1.0000	
X VALUE WHERE SECTION AREA IS MAX	4.20000	
	FOREBODY	AFTBODY
PRISMATIC COEFFICIENT	0.6902	0.7337
X VALUE WHERE SA CURVE HAS ZERO SLOPE	4.0000	5.0000
LENGTH OF PARALLEL MIDBODY	0.2000	0.8000
LCG (ABOUT X AT MAX SA)	1.5381	2.2292
RADIUS OF GYRATION (ABOUT X AT MAX SA)	1.8176	2.6257

DERIVED SECTION AREA CURVE-ACTUAL VALUES	(PROGRAM OUTPUT)	
	FOREBODY	AFTBODY
CHANGE IN PRISMATIC COEFFICIENT	-0.0298	-0.0050
LCG OF CHANGE IN CP (ABOUT X AT MAX SA)	2.6916	3.9028
	TOTAL CON UNEVEN SPACING)	
PRISMATIC COEFFICIENT	0.7000	
PERCENT CP ERROR (ACTUAL VS DESIRED)	0.0024	
LCB (ABOUT ORIGIN)	4.9492	
PERCENT LCB ERROR (ACTUAL VS DESIRED)	-0.0155	
	TOTAL (ON EVEN SPACING)	
PRISMATIC COEFFICIENT	0.7000	
PERCENT CP ERROR (ACTUAL VS DESIRED)	0.0046	
LCB (ABOUT ORIGIN)	4.9495	
PERCENT LCB ERROR [ACTUAL VS DESIRED)	-0.0110	



PARENT. WITH PARALLEL MIDBODY
DERIVED. SHIFT LCB AFT.DECREASE CP.SET F/A BOUNDARY

A NEW APPROACH TO FABRICATION DRAWINGS

D. P. Ross
Vice President, Marketing and N/C Services
Cali & Associates Inc
New Orleans, Louisiana

Mr. Ross has been with Cali & Associates Inc for 6 years. The prior 17 years he has served in various capacities at Ingalls Shipbuilding including the production and engineering departments. He has been involved in N/C lofting/design for 11 years.

ABSTRACT

In this paper a problem is discussed that has existed in the shipbuilding industry for many years; that is how to present to production workers fabrication drawings that are more accurate, less cumbersome and easily understood. An approach to solving this problem through use of N/C lofting software is presented and discussed.

INTRODUCTION

For many years the shipbuilding industry has recognized the fact that skilled craft workers are becoming more difficult to find.

The skilled Shipfitter of years past is practically non-existant today. This person worked with large, cumbersome detail drawings that were prepared for regulatory body approval, along with full size templates furnished by the Mold Loft, where applicable.

In order to fabricate one unit of a vessel it was usually necessary to work with several large drawings for structures such as Shell Plating, Decks, Transverse Floors, Transverse Bulkheads, Longitudinal Bulkheads and Longitudinal Girders. Since these drawings were prepared for one third to one half of the vessel, a great deal of redundant information had to be sorted out by the Shipfitter.

In order to reduce the skill level requirement of the Shipfitter several new processes have been developed such as N/C Lofting and Plate cutting. While these processes reduced the fitting and welding man hours they did not eliminate the problem of cumbersome, difficult to understand drawings which were still necessary to fabricate the structure.

In recent years several new approaches have been made to provide fabrication drawings that are easily understood by the average craft person within the industry. These drawings are generally prepared by hand and are subject to the usual error of this process.

This paper will discuss a new approach to preparation of fabrication drawings utilizing previously generated N/C Lofting information.

THE CONCEPT

The concept of developing the fabrication drawings from previously developed N/C Lofting data came about recently as a result of the needs of a new shipyard, Upper Peninsula Shipbuilding Company. This totally new facility was to employ a local work force with no prior shipbuilding experience, therefore it was imperative that the fabrication drawings be simplified as much as possible.

Working with Breit & Garcia, the design Agent for UPSCO, Cali & Associates is developing the fabrication drawings for the first vessels being constructed in the new facility at Ontonogan, Michigan. To date, approximately one third of the structural units for the Tug of a Tug/Barge combination have been constructed utilizing the N/C Lofting data and Fabrication Drawings.

DEVELOPMENT

As can be seen from the Functional Diagram, Figure 1, the development of Fabrication Drawings does not require anything exceptional or out of the ordinary within the normal operational cycle. Some additional work is required by the N/C Loft and the Design Department which will be covered in more detail further on.

The general evolution from Design to Production, as depicted in Figure 1, is as follows:

> Utilizing Contract Scantling Drawings or Detail Design Drawings the Production Department decides on the Unit breakdown, erection sequence, and welding details for

the vessel. This information is relayed to the Design Department for inclusion on drawings as necessary.

(Figure 2)

The Design Department adds erection information to the drawings such as butts, seams and welding details as required by the Production Department, for subsequent issue to the N/C Loft.

(Figure 3)

The N/C Loft, utilizing Scantling or Detail Drawings issued by the Design Department along with written planning information from the Production Department, produces all the individual parts, templates, nest tapes, stiffener data and Bills of Material required for each defined structural unit.

(Figures 4 & 5)

Upon completion and validation of all parts within a Unit, the N/C Loft prepares the background fabrication drawings utilizing the previously defined parts and a feature within the "SPADES" software that allows these parts to be drawn in their proper relationship to each other, since they have been defined within the ship's coordinate system. These drawings, by virtue of the parts having been programmed to include labeling, have all the required piece mark identification as well as reference lines and orientation.

(Figure 6)

A recently added. feature of the "SPADES" software allows the direct generation of a panel drawing for flat rectangular parts with all identification labeling, locating dimensions for attaching structure and check dimensions for alignment checks. Dimensions are all provided by the system, from the Data Base, and not from input by the part programmer. This assures accuracy and control of the data provided to the Production Department.

(Figure 7)

The Design Department completes the Fabrication Drawing generated in the N/C Loft by adding welding, standard detail call-outs and any notes that might be required. This drawing is then issued to the Production Department for subsequent use of the Shipfitters in assembly of the Units.

(Figure 8)

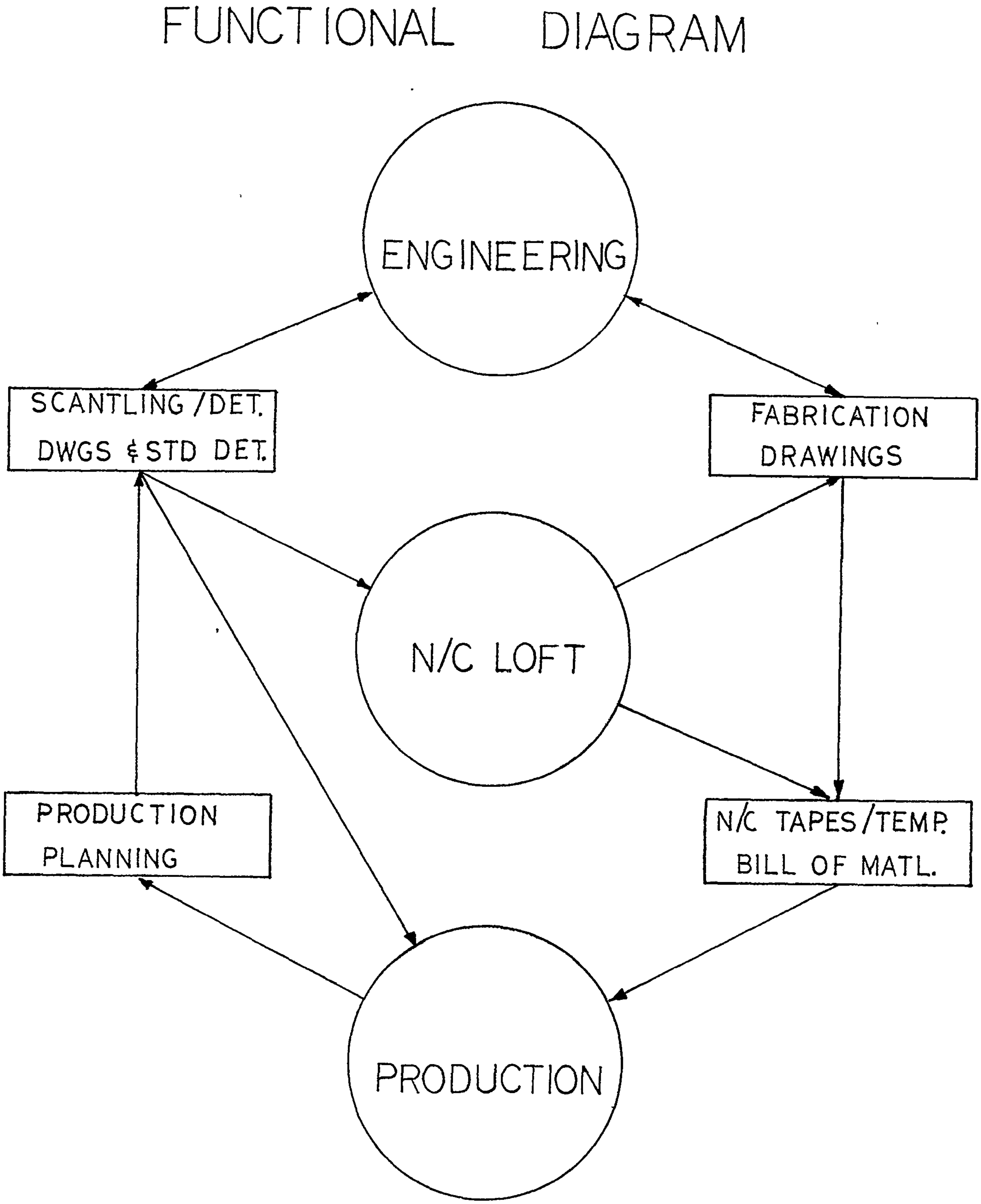

FUNCTIONAL DIAGRAM
ENGINEERING
SCANTLING/DET.
DWGS & STD DET.
FABRICATION
DRAWINGS
N/C LOFT
PRODUCTION
PLANNING
N/C TAPES/TEMP.
BILL OF MATL.
PRODUCTION

FIGURE 1

PRODUCTION PLANNING

UNIT DESCRIPTION

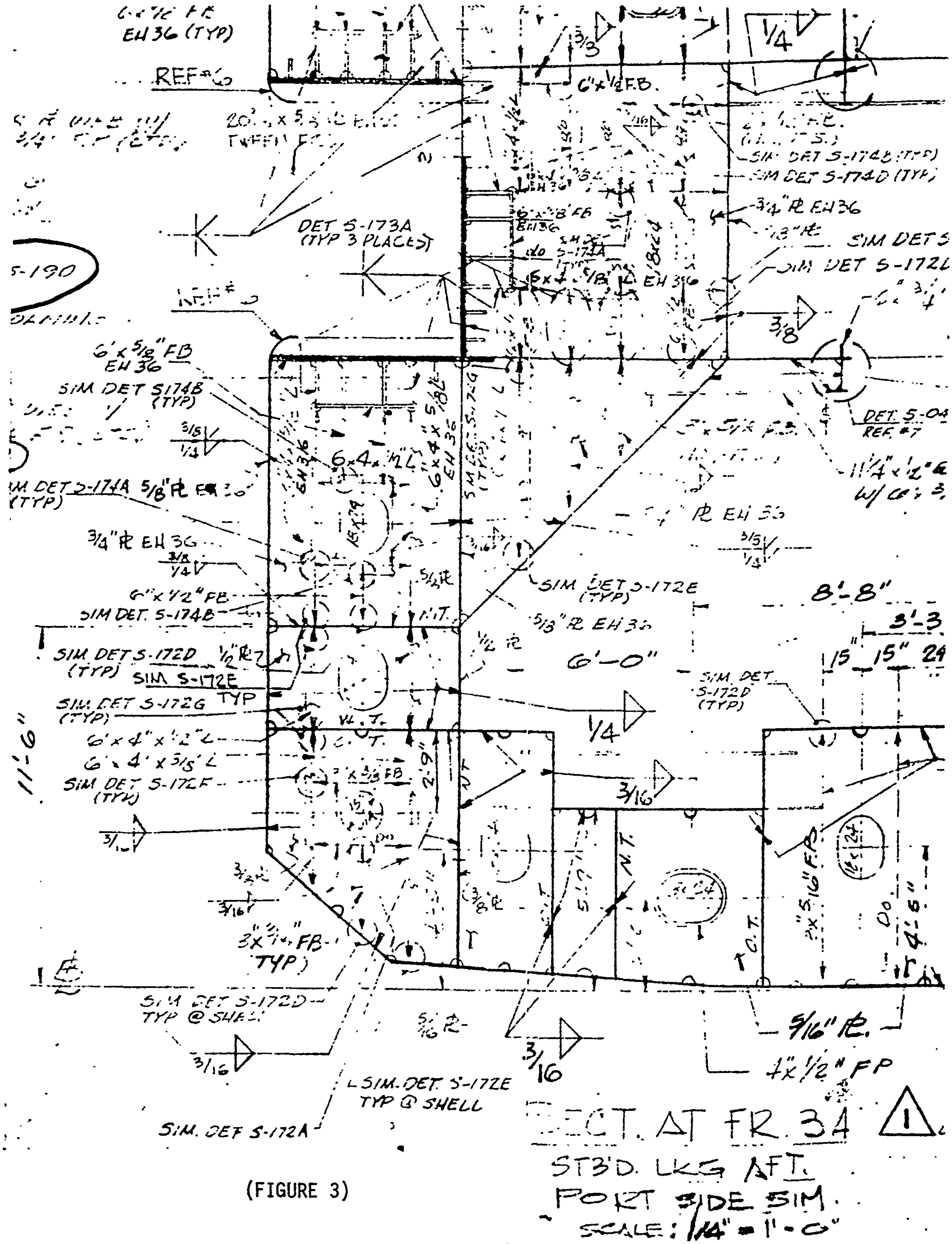
UNIT NO: 10

TITLE: WING TANK FR. 29-42 STBD.

DESCRIPTION:

THIS UNIT TO BE ASSEMBLED USING WING TANK BULKHEAD AS A BASE. PANEL WELD BULKHEAD AND ERECT FRAMES ON SAME. PANEL WELD MAIN DECK, FIT AND WELD TO PREVIOUSLY ERECTED FRAMES. FIT AND WELD SHELL PLATES, TACK WELDING ONLY TO FRAMES. ROLL UNIT ONTO SIDE SHELL AND COMPLETE WELDING DOWNHAND. LEAVE 1" STOCK ON FORWARD END OF UNIT.

FIGURE 2


EH 36 (TYP)
REF #6
6"x½"F.B.
DET S-173A
(TYP 3 PLACES)
SIM DET S-174B (TYP)
SIM DET S-174D (TYP)
¾" ℞ EH36
SIM DET S-172E
6'x⅝" FB
EH 36
SIM DET S174B
(TYP)
SIM DET S-174A
(TYP)
⅝" ℞ EH 36
¾" ℞ EH 36
6"x½" FB
SIM DET. S-174B
SIM DET S-172D
(TYP)
SIM S-172E
TYP
SIM DET S-172G
(TYP)
6"x 4" x ½" L
6" x 4" x ⅝" L
SIM DET S-172F
(TYP)
11'-6"
SIM DET S-172E
(TYP)
8'-8"
3'-3
6'-0"
15" 15"
SIM DET
S-172D
(TYP)
N.T.
3x¼" FB
TYP
SIM DET S-172D
TYP @ SHELL
SIM. DET. S-172E
TYP @ SHELL
SIM. DET S-172A
5/16" ℞.
4" x ½" FP
4'-6"
DET S-04
REF #7
SECT. AT FR. 34
STB'D. LKG AFT.
PORT SIDE SIM.
SCALE: ¼" = 1'-0"

(FIGURE 3)

```
*****************************************************************************
*                                                                           *
*            U P P E R   P E N I N S U L A   S H I P B L D G .              *
*       --------------------------------------------------------           *
*                                                                           *
*                              U P S C O   T U G                            *
*****************************************************************************
*                                                                           *
* NO.PLATES LIKEWISE =  1 NO.PLATES MIRROR IMAGE=  0 TOTAL NO. PLATES =  1*
*                                                                           *
* PLATE SIZE = 38600X 9800X 51 STOCK NO.=                  MTL.= STEEL      *
*                                                                           *
*****************************************************************************
*                                                                           *
*            P A R T S   N E S T E D   T H I S   T A P E                    *
*                                                                           *
*      PART NO.        QTY.        PART NO.        QTY.       PART NO.        QTY. *
*   -------------------     -------------------    -------------------     *
*   14   60F       2/     1   14   60F        1/     1   14   CLR       1/    10  *
*   14   CLR       2/    10   14   CLR        4/     2   14   50F      51/     2  *
*   14   50F       4/ S   1   14   50F        4/ P   1   14   51F       4/ S   1  *
*   14   51F       4/ P   1   14   55F        4/ S   1   14   55F       4/ P   1  *
*                                                                           *
*                                                                           *
*                                                                           *
*                                                                           *
*                                                                           *
*                                                                           *
*                                                                           *
*****************************************************************************
*                              R E V I S I O N S                            *
*****************************************************************************
* REV *                        DESCRIPTION                       * BY * DATE *
*****************************************************************************
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*     *                                                          *    *       *
*****************************************************************************
*                                                                           *
*                                PREPARED BY                                *
*                                                                           *
*           C A L I  &  A S S O C I A T E S ,  I N C .                      *
*      ---------------------------------------------------------            *
* CHECKED BY:                            VALIDATED BY:                      *
*****************************************************************************
* JOB NO.9026UP01                      NEST TAPE NO.    4610144- 3   /      *
*****************************************************************************
```

FIGURE 4

SPARES SYSTEM DATE 10/03/80

IDENTIFICATION & PLOT LOCATION OF PARTS
FOR TAPE NO. 4610144- 3

PLOT REF.	DRWG. & LOC.	M/C ID & MODE	LIKE PLATE MODULE & REMK.	MIRR. PLATE MODULE & REMK.
1	14	0421-302- 1 L	14 60F 2/	
2	14	0421-301- 1 L	14 60F 1/	
3	14	0431- 3- 4 L	14 CLR 1/	
4	14	0431- 4- 4 L	14 CLR 2/	
5	14	0431- 2- 4 L	14 CLR 4/	
6	14	0432- 1- 2 L	14 50F 51/	
7	14	0404- 1- 3 L	14 50F 4/ S	
8		M	14 50F 4/ P	
9	14	0404- 2- 3 L	14 51F 4/ S	
10		M	14 51F 4/ P	
11	14	0404- 6- 3 L	14 55F 4/ S	
12		M	14 55F 4/ P	

*****

FIGURE 4 a

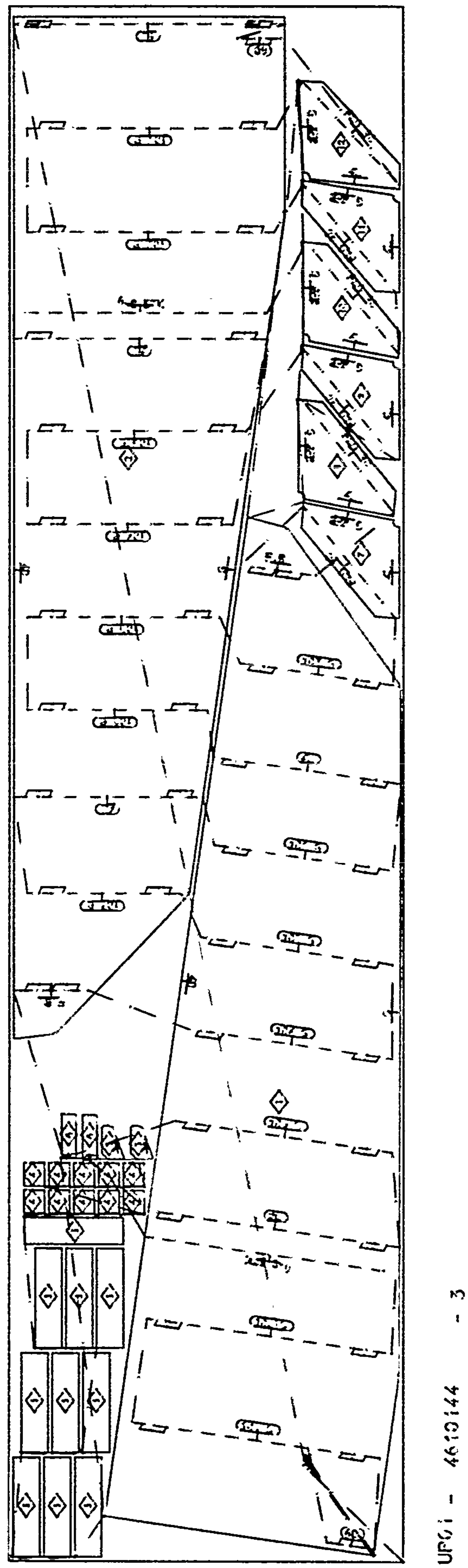


FIGURE 4 b

S P A D E S   S Y S T E M   DATE 10/03/80

SUMMARY REPORT OF BURNING TAPE NO.   4610144 - 3

PIERCING TIME	0.0	(PIERCING ALLOWANCE 0.0/ 0.0 MIN.)
RAPID TRAVERSE TIME	10.2	(ASSUMED SPEED 250.0 IN./MIN.)
CENTER PUNCHING TIME	5.7	(ASSUMED SPEED 250.0 IN./MIN.)
BURNING TIME	30.0	(ASSUMED SPEED 90.0 IN./MIN.)
TOTAL PROCESSING TIME	46.0	MINUTES

POST PROCESSOR OPTIONS USED FOR TAPE :

FORMAT : EIAS

CUTTING PROCESS : PLSM

PAPER TAPE PARITY : EVEN

PLATE OUTLINED BY : D.M.

KERF COMPENSATED BY AUX. FUNCTION

LABEL MARKING OFT IONS:.   11

NO OF STOPS PROGRAMMED IN THE TAPE : 4

MATERIAL UTILIZATIONS DATA

PLATE UTILIZATION = 83.9 PERCENT

SCRAP WEIGHT = 540.2 POUNDS

TYPE OF MATERIAL STEEL

FIGURE 4 c

REPORT DATE : 9/11/80
D.B.NAME : UP01 9026UP01
VESSEL : UPSCO TUG

S P A D E S S Y S T E M
SHIP PRODUCTION AND CONTROL MODULE

PAGE NO. 0. 1
MODULE/UNIT: 10
REPORT REV. 1

TOTAL WEIGHT FOR SHAPES: 6831.7 LBS.
TOTAL WEIGHT FOR PLATES: 74252.2 LBS.
TOTAL WEIGHT FOR MODULE: 81083.9 LBS.

FIGURE 5

REPORT DATE : 09/11/80
D.B.NAME : UP01 9026UP01
VESSEL : UPSCO TUG

S P A D E S S Y S T E M
SHIP PRODUCTION AND CONTROL MODULE

PAGE NO. 3. 1
MODULE/UNIT: 10
REPORT REV. 1

PIECES PRODUCED FROM SHAPES

LINE-REV	PIECE MARK/ DRAWING NO.		QTY/ LOC.	WGT.	MAT'L	LENGTH	STK	'A'	'B'	'C'	N/C ID	WEB 1 FLANGE 1		WEB 2 FLANGE 2		OTHER N/C DESCRIPTION	AIDS
1- 1	29F	101	2	141	0S 668	11-05-08		11-05-08			0	B	C-04	T	C-04	0	0
2- 1	31F	101	1	97	0S 668	7-10-13					0		C104		C-02	0	0
3- 1	31F	102	1	72	0S 668	5-10-06					0		C-04		C102	0	0
4- 1	31F	103	1	55	0S 670	3-05-00		3-05-00			0	B	C-04	T	C102	0	0
5- 1	31F	104	1	63	0S 670	3-11-00		3-11-00			0	B	C-04	T	C101	0	0
6- 1	31F	105	1	107	0S 670	6-07-00		6-07-00			0	B	C-04	T	C102	0	0
7- 1	32F	101	1	95	0S 668	7-08-07					0		C104		C-02	0	0
8- 1	32F	102	1	69	0S 668	5-07-10					0		C-04		C102	0	0
9- 1	32F	103	1	55	0S 670	3-05-00		3-05-00			0	B	C104	T	C-02	0	0
10- 1	32F	104	1	86	0S 670	5-04-00		5-04-00			0	B	C104	T	C-02	0	0
11- 1	32F	105	1	107	0S 670	6-07-00		6-07-00			0	B	C104	T	C-02	0	0

FIGURE 5 a

REPORT DATE : 9/11/80 | SPADES SYSTEM | PAGE- NO. 6. 1
D.B.NAME : UP01 9026UP01 | SHIP PRODUCTION AND CONTROL MODULE | MODULE/UNIT: 10
VESSEL : UPSCO TUG | | REPORT REV. 1

PLATE MATERIAL LIST

LINE	STOCK NO.	GRADE	SIZE	QTY.	N/C-TAPE ND.	PRC.TIME	LOC.	NOTES:
1		STEEL	38600X 9800X 25	2	4610073-14	47.8		
2		STEEL	38603X 9800X 25	1	461CC78- 4	47.7		
3		STEEL	38600X 9800X 25	1	4610079- 3	44.1		
4		STEEL	38600X 9800X 38	2	4610081- 3	55.4		
5		STEEL	38600X 9800X 38	2	4610084- 3	42.1		
6		STEEL	38600X 9800X 50	2	4610089- 5	167.9		
7		EH36 STL	48000x 7400x 75	2	4610090- 6	49.3		
8		STEEL	38600X 9800X 62	1	4610091- 6	94.1		
9		STEEL	38600X 9800X 50	1	4610099- 5	156.5		
10	BEVELS	EH36 STL	48000X10200X 62	2	4610102- 4	147.1		
11		STEEL	38600X 9800X 25	1	4610103- 3	41.7		
12		STEEL	38600X 9800X 38	2	4610014- 6	146.4		
13		STEEL	38600X 9800X 38	1	4610105- 4	72.8		
14	BEVELS	EH36 STL	48000X10200X 75	1	4613106- 3	114.4		
15	REVELS	STEEL	38600X 9800X 50	1	4610108- 4	169.0		
16		STEEL	38600X 9800X 75	1	4610110- 3	79.1		
17	BEVELS	STEEL	38600X 9800X 62	1	4610111- 6	172.7		

FIGURE 5 b

REPORT DATE : 9/11/80 | S P A D E S S Y S T E M | PAGE NO. 7. 1
D.B.NAME : UP01 9026UP01 | SHIP PRODUCTION AND CONTROL MODULE | MODULE/UNIT: 10
VESSEL : UPSCO TUG | REPORT REV. 1

PIECES PRODUCED THROUGH N/C CUTTING

	LINE-REV		PIECE	MARK	DRAWING NO.	LOC.	QTY.	WGT.	HAT.	THK.	STK	N/C ID.	NEST TAPES	TEMPLATES	PROCESS IST	PROCESS 2ND	DESCRIPTION
	l-	1	10D	1			1	531	0	.62		0335- l- 2	10115- 3				
	2-	1	1D	1	9-10		1	715	0	.50		0335- 2- 2	10113- 7				
	3-	1	1D	2	9-10		1	952	0	.38		0335- 3- 2	10112- 2				
	4-	1	27D	1	9-10		3	364	0	1 50		0330- l- 4	10108- 4				
	5-	1	29F	1			1	635	0	.38		0299- l- 2	10081- 3				
w	6-	1	29F	2			1	1034	0	.38		0311- l- 4	10122- 6				
85	7-	1	29F	51			1	30	0	.38		0299- 2- 2	10081- 3				
	8-	1	29f	52			1	24	0	.38		0299- 3- 2	10081- 3				
	9-	1	29F	53			4	11	a	.38		0311- 2- 4	10122- 6				
	l0-	1	29F	54			2	13	0	.38		0311- 3- 4	10122- 6				
	1l-	1	30F	1			1	630	0	.38		0299- 5- 2	10081- 3				
	12-	1	30F	2			1	262	0	.38		0312- l- 2	10122- 6				
	13-	1	31F	51			1	30	0	.38		0299- 6- 2	10081- 3				
	14-	1	30F	52			1	24	0	.38		0299- 7- 1	10081- 3				
	15-	1	30F	53			2	11	0	.38		0312- 2- 2	10122- 6				
	16-	1	31F	1			1	618	0	.38		0220- 1- 5	10081- 3				
	17-	1	3lF	2			1	1925	3	.75		0313- l- 3	10119- 2				

FIGURE 5 c

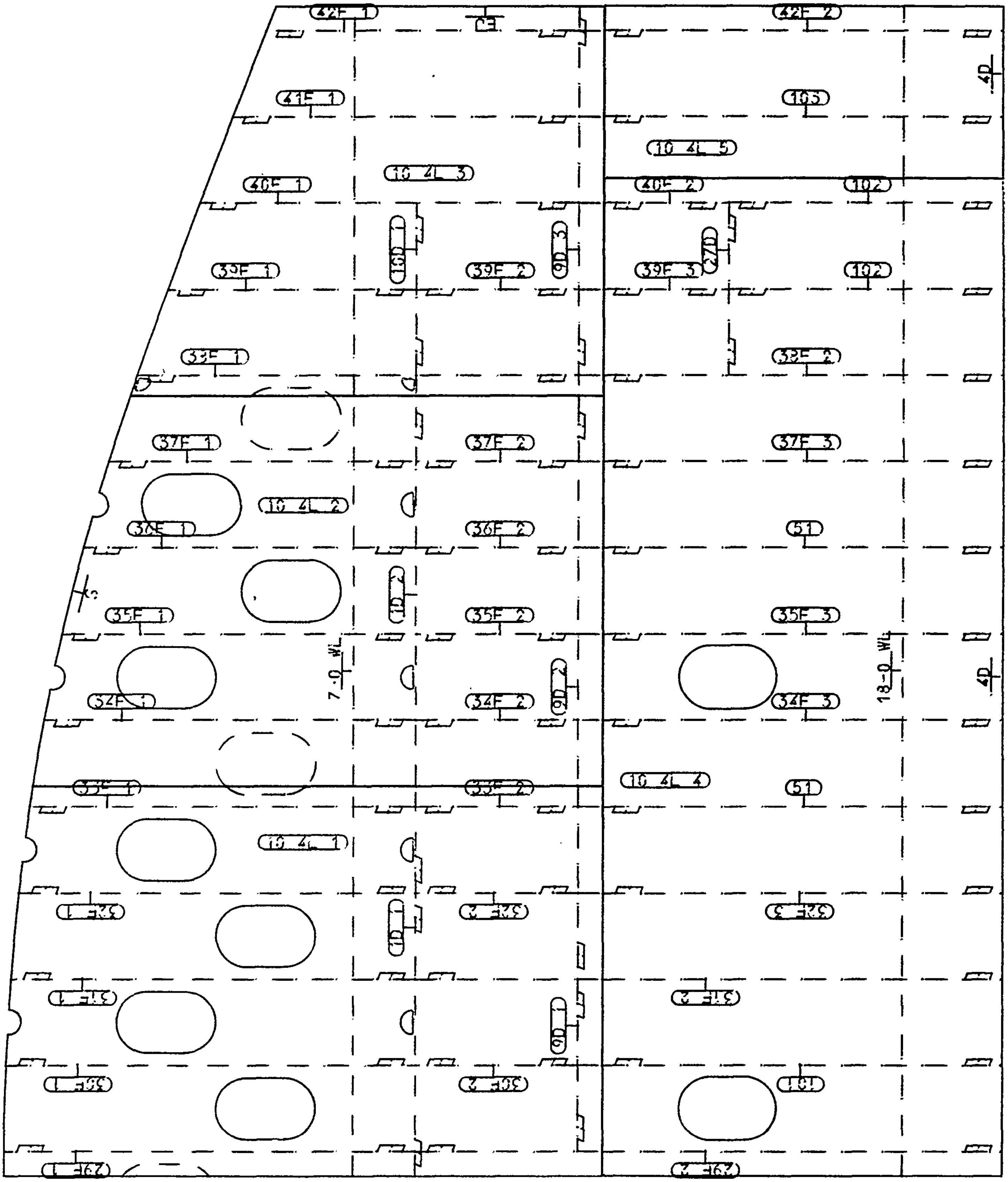
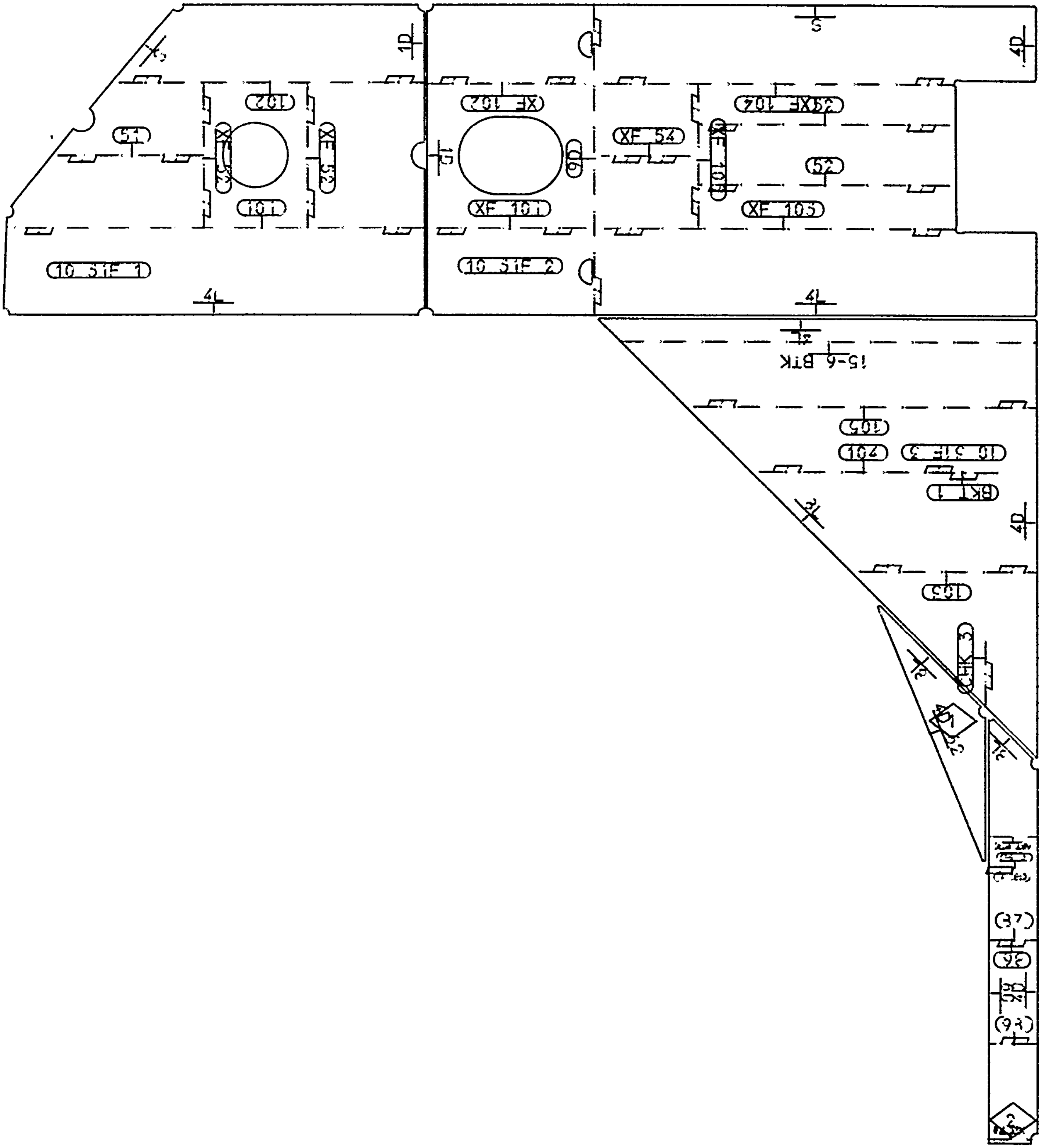

42F 1
42F 2
CE
4D
41F 1
105
10 4L 5
10 4L 3
40F 1
40F 2
102
1D 1
9D 3
27D
39F 1
39F 2
39F 3
38F 1
38F 2
37F 1
37F 2
37F 3
10 4L 2
36F 1
36F 2
51
1D 2
35F 1
35F 2
35F 3
7-0 WL
9D 2
34F 1
34F 2
34F 3
18-0 WL
10 4L 4
33F 1
33F 2
10 4L 1
1D 1
9D 1

FIGURE 6



1D
5
4D
102
XF 102
XF 104
XF 54
52
51
101
XF 101
XF 105
10 STF 1
10 STF 2
4L
15-6 BTK
105
104
10 STF 3
BKT 1

FIGURE 6 a

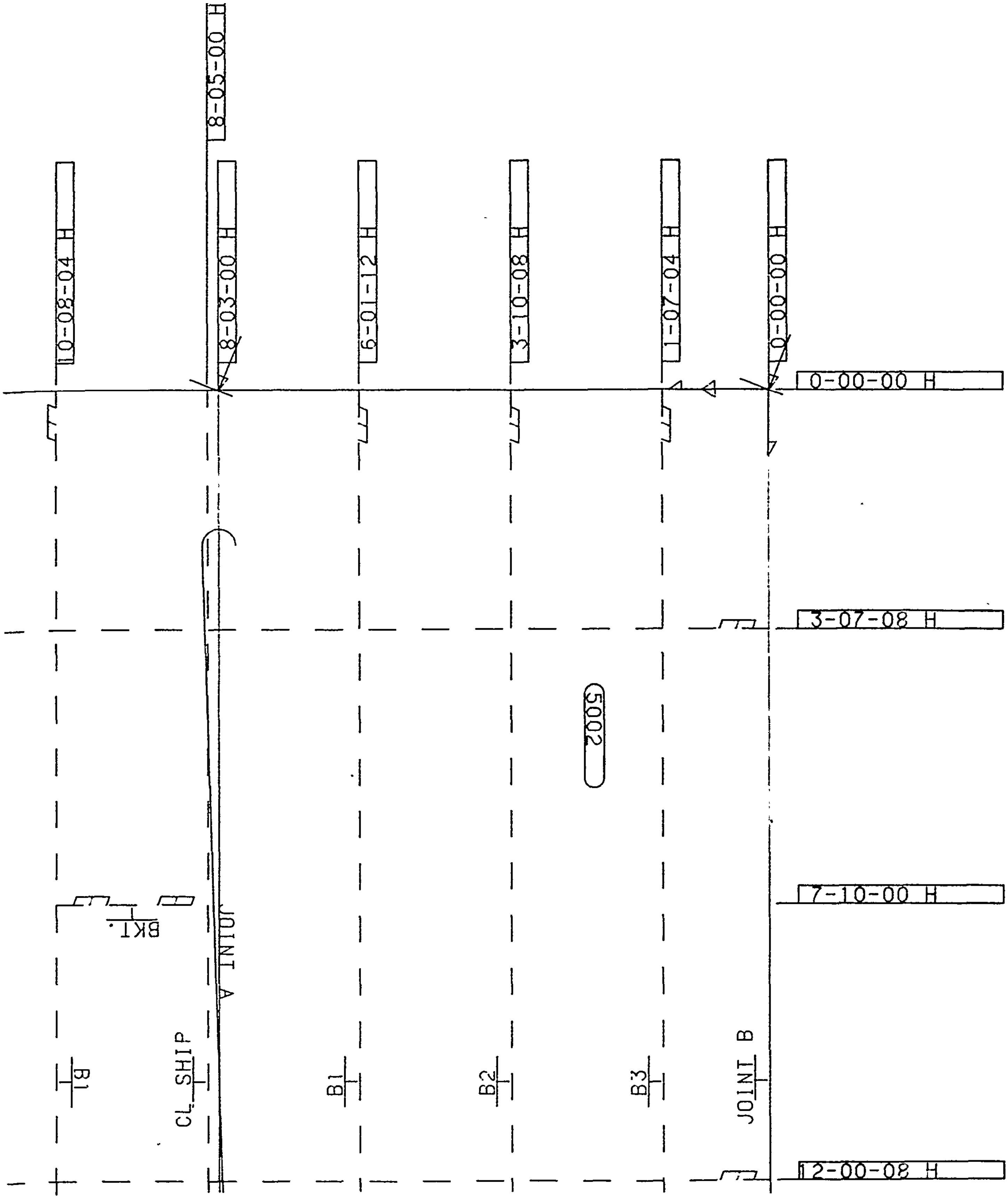
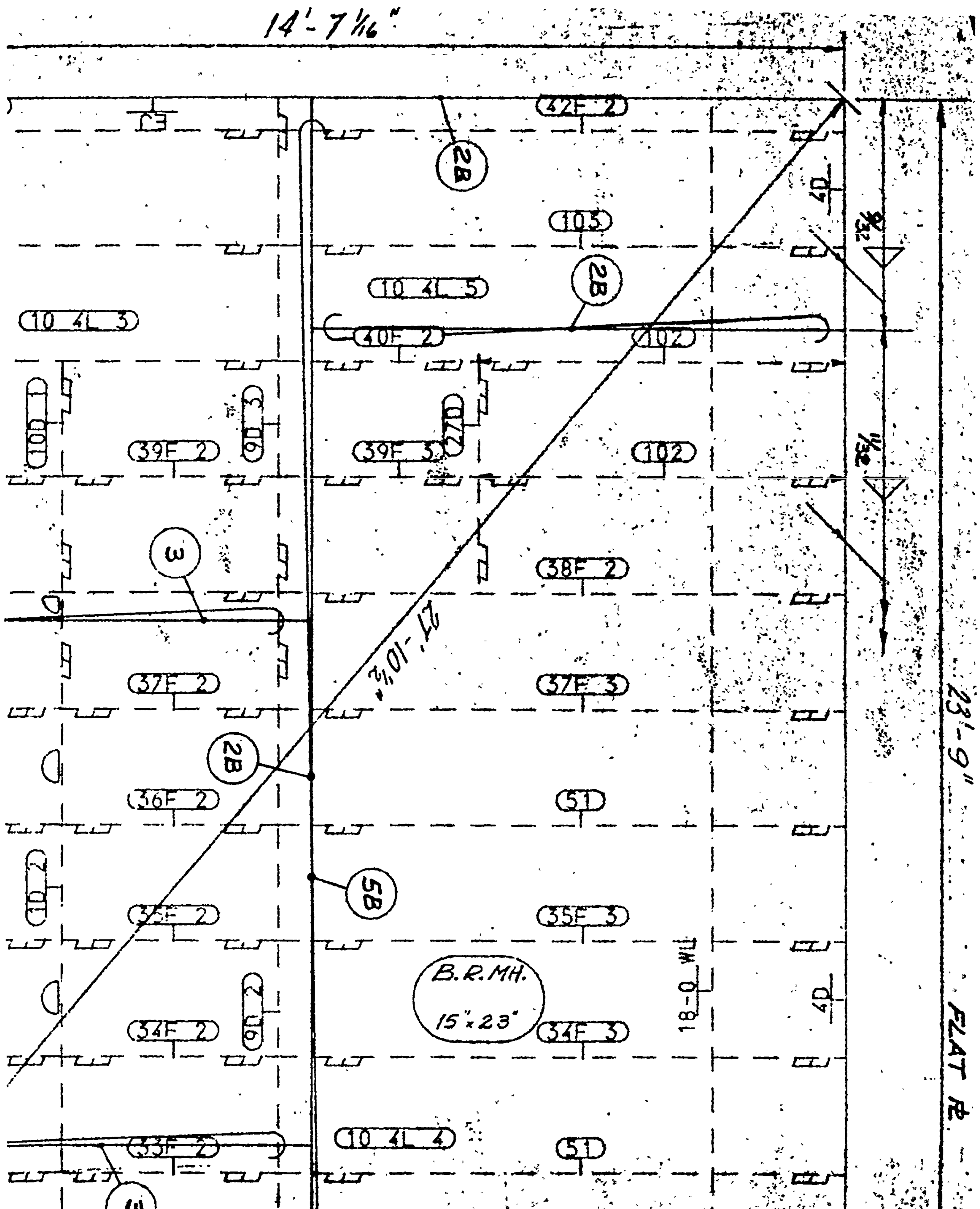

8-05-00 H
10-08-04 H
8-03-00 H
6-01-12 H
3-10-08 H
1-07-04 H
0-00-00 H
0-00-00 H
3-07-08 H
5002
7-10-00 H
BKT.
JOINT A
B1
CL SHIP
B1
B2
B3
JOINT B
12-00-08 H

FIGURE 7



14'-7 1/16"
27'-10 1/2"
23'-9"
FLAT PL.
B.R.MH.
15" x 23"
18-0 WL
2B
2B
2B
3
3
5B
42F 2
105
10 4L 5
10 4L 3
40F 2
102
102
10 1
9D 3
27D
39F 2
39F 3
38F 2
37F 2
37F 3
36F 2
51
10 2
35F 2
35F 3
9D 2
34F 2
34F 3
10 4L 4
33F 2
51
4D
4D

FIGURE 8

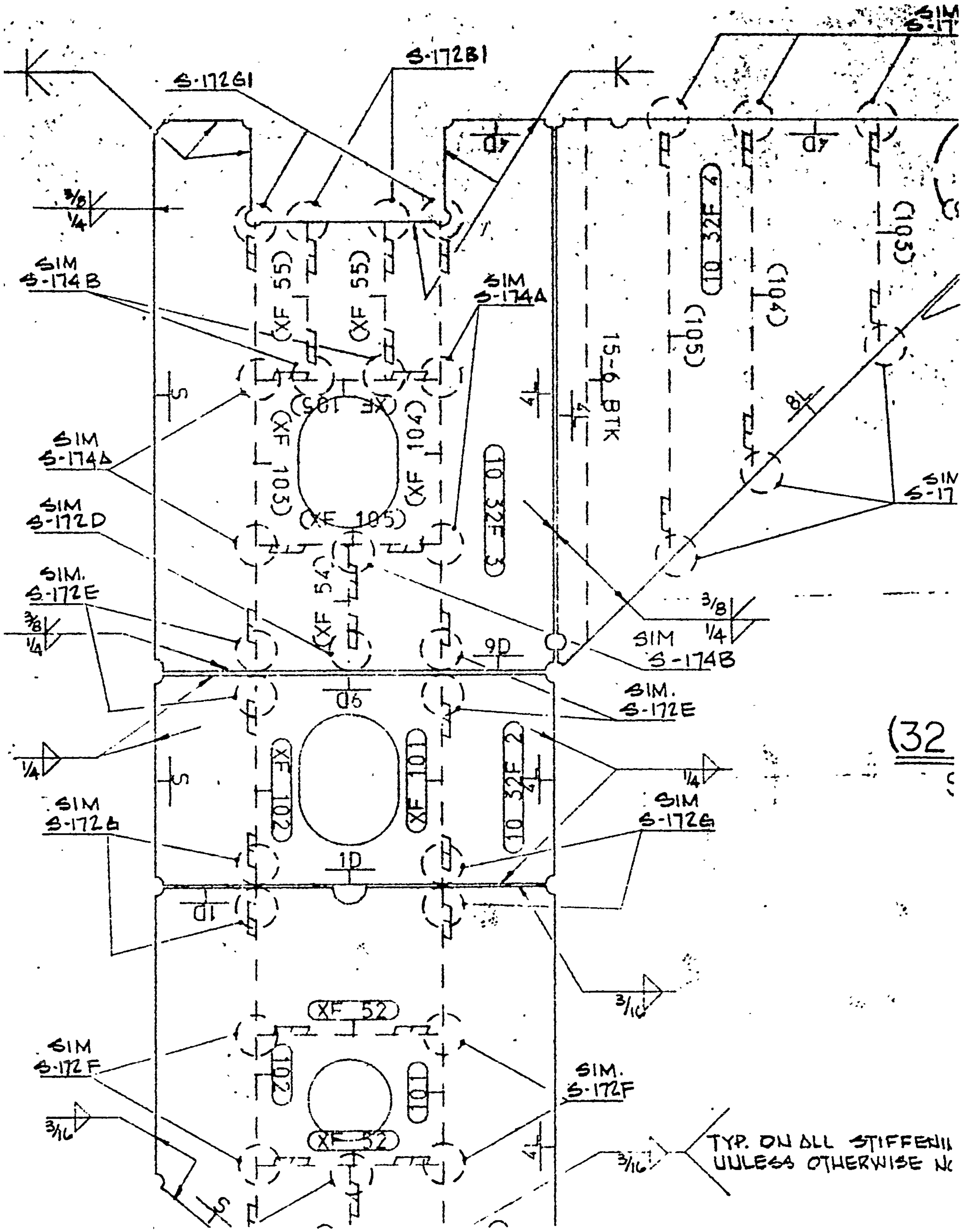

S-172B1
S-172G1
SIM S-174B
SIM S-174A
SIM S-174A
SIM S-172D
SIM. S-172E
SIM S-172G
SIM S-172F
SIM. S-172F
SIM S-174B
SIM. S-172E
SIM S-172G
(XF 55)
(XF 55)
(XF 105)
(XF 103)
(XF 104)
(XF 105)
(XF 54)
10 32F 3
10 32F 4
10 32F 2
15-6 BTK
(105)
(104)
(103)
XF 102
XF 101
XF 52
102
101
XF 52
9D
D6
1D
1D
(32
TYP. ON ALL STIFFENI
UNLESS OTHERWISE N

FIGURE 8 a

CONCLUSION

Reports from Upper Peninsula Shipbuilding indicate the Fabrication Drawings being used are a total success in that people without prior shipfitting experience are doing an excellent job in fabrication of the Tug Boat.

As experience is gained, and particularly through use of Interactive Graphics, the time to produce the Fabrication Drawings is being reduced considerably. A conservative estimate would place the cost to produce the drawings in this manner at about twenty five percent (25%) of the cost to prepare them entirely by hand.

Since the lofting effort is mandatory to the construction of a vessel, it seems that the development of Fabrication Drawings should be handled as described in this paper in order to take full advantage of the inherent accuracy and reduced man hours.

EVALUATION OF ALTERNATIVE GENERIC COATINGS IN DIFFERENT SHIP AREAS

Benjamin S. Fultz
Offshore Power Systems
Jacksonville, Florida

ABSTRACT

The information contained within this presentation was obtained from a research project performed under the National Shipbuilding Research Program. The project was a cooperative cost shared effort between the Maritime Administration, Avondale Shipyards, Inc, and Offshore Power Systems, a wholly owned Westinghouse subsidiary. The overall objective of the program was to improve productivity and, therefore, reduce shipbuilding costs to meet the lower construction differential subsidy rate goals of the Merchant Marine Act of 1970.

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Toward this end, the following results were achieved to improve the paint system selection process:

- Establishment of a computer program of paint service histories which demonstrates that valid conclusions can be reached as to which generic paint type is best for a specified area of this ship.
- Support by laboratory testing of performance trends of the computer program analysis.
- Demonstration by laboratory testing that careful evaluation of paint suppliers is necessary.
- Indications that careful selection of laboratory test methods and evaluation parameters, to duplicate service conditions, can serve as a screening method for candidate paint(s).
- Identification of craft interference and premature area release for painting prior to compartment completion. That is, poor paint planning and scheduling is the major cause of inordinately high ship painting costs.

As most practitioners of the marine coatings profession can attest to, the selection of a coating system for new ship construction is often thought of as a "crystal ball" art form. Today there are numerous different generic paint types in the marine market place, each of which is advertised as the epitome of excellence. The shipowner is often misled into selecting exotic paint systems with high initial cost on the premise that the higher the initial cost, the more extended the performance without maintenance. This selection method does not always hold true. The system application may require extensive controls beyond the state-of-the-art capabilities of the prospective builder. The end result is an expensive system applied under other than ideal conditions leading to inferior performance.

Likewise, the selection of a low initial cost, short life system may lead to major maintenance and upkeep costs. In neither case is the system cost effective. Therefore, the shipowner is left in a quandary. He has no reference source document to help him select the correct paint system for the intended use or service condition.

If the principles identified within this talk are assimilated by the marine industry, millions of dollars in improved ship paint performance will be realized. Marine Industries will benefit in three ways:

- Less dollars expended at guarantee survey time due to improved paint performance (fewer failures).
- Reduction in the probability of a catastrophic paint failure during vessel construction.
- Increased operational efficiency of ships in service.

As originally envisioned, the project was broken into six tasks. The first three tasks concerned the establishment of evaluation criteria. The remaining tasks concerned the compilation of data and the analysis of results. The paragraphs which follow discuss the sequence of events leading to, and the rationale behind, the selection of evaluation criteria and final systems analysis.

To establish evaluation criteria, questionnaires were sent to major U. S. Shipyards, major marine coatings suppliers and ship owner/operators. The most disappointing responses were received from the owner/operator group. Out of the ninety-five polled, only one provided substantial information.

As a result of the surveys, questionnaire responses and literature reviews, the "Ships/Paints Coatings Performance'Service Histories Questionnaire" was formulated.

As can be seen from the slide, the form is simple, straight forward with little room for interpretation, readily adaptable to rapid keypunch. This form incorporates the following information:

- Ship types representative of the different service conditions
- Types of coatings used
- Inspection criteria and frequency
- Means of documentation

The major effort expended in this project was toward the systematic collection of historical paint performance data. The final report contains the following number of case histories:

Underwater Bottom	282 histories
Underwater Bottom Flats	70 histories
Underwater Bottom Sides	70 histories
Boottop	217 histories
Freeboard	134 histories
Decks	54 histories
Superstructure	36 histories
Cargo Holds & Spaces	17 histories
Product Tanks	156 histories
Ballast Tanks	36 histories
TOTAL	1,072 histories

The numbers of histories are impressive but incomplete to perform a true comparative performance analysis. However, some trends can be noted. With an enlarged data deck for reference, more definitive conclusions can be made. The inspection data was processed into an analysis deck which was then used to provide detailed information on specific service histories. Each service history has a separate, distinct control number. This number does not appear in the final report. It is'printed on the right hand tear-off margin. The code number is unique in that it identifies the source of data and a numerical sequence. Close scrutinization between this code number and the rating of a given service history can result in the rejection of some supplied data.

For example, a biased source may desire to make a given generic material appear to possess better than true, actual performance characteristics. Close examination of the service history, by a knowledgeable individual, can normally detect favoritism; e.g., all extremely good reports with no failures. The philosophy used throughout this study was "When in doubt, do not use the information". With a larger data base, this judgment can be made statistically by determination of a variance from the true mean.

The compiled data is presented in tabular form, and the columns of the report from left to right are explained as follows:

TYPE OF SHIP - Self explanatory. Even though exact ship sizes are not given, a general idea can be gained. Small craft and barges are identified.

TRADE ROUTE - Self explanatory.

AREA/SYSTEM - The first print gives a description as to which performance area of the ship is being evaluated. Each ship is divided into eight different areas. Listed under the area is the generic paint system used to include number of coats.

SURFACE PREPARATION - The codes used are the Steel Structures Painting Council Surface Preparation Standards or a description of the process.

SYSTEM AGE - This is the actual age of the system being rated. It could be the same as the ship's age if the evaluation was completed during the initial survey period, or it could be the time since the last overhaul if the system was applied at that time. Old, intact material could be a part of the system if retained after the completion of the overhaul surface preparation.

FILM THICKNESS - Actual average film thickness of each coat of paint.

SHIP'S AGE - Age of the ship counted from initial delivery of the ship from the shipyard to the owner.

PERFORMANCE EVALUATION - This section is broken into five parts for underwater bottom evaluations and three parts for all others.

% CORROSION - This is the actual percent of corrosion (rust) of the surface expressed as a %. The rating takes into consideration the entire surface area and does not attempt to define extreme localized failures.

% COATINGS FAILURE - By definition this is a measure of the system's inability to perform its intended purpose. This could be a fouling failure, corrosion failure, cosmetic failure or a system failure; i.e., a delamination between coats of paint. This number is always the larger of the numbers which express % fouling, corrosion or other failure.

% FOULING - Measure of the amount of surface area fouled. For example, a ship may have 100% fouling between the waterline and six feet below the waterline. The remainder of the hull may be free of all fouling. The system would not be considered as 100% fouled but at some percent which takes into consideration the entire hull surface area. Since this particular phenomenon is common to underwater bottoms, an attempt was made to rectify the situation by dividing the underwater bottom into two additional subareas, namely underwater bottom-flats and underwater bottom-sides.

TYPE FOULING - Self explanatory. This is important because some types of fouling have more of an influence over ship performance to include increased fuel consumption. Shell has a maximum influence; slime has minimum influence.

The data bank can be sorted into three different catagories:

- Type of ship
- Trade Route
- Functional Performance Area

The histories are then automatically ranked and placed in order of performance, the best performances being listed first.

From the data contained within the data bank, a comparative analysis can be performed on the relative performance of different generic paint systems within a given functional area. As an example, the underwater bottom area to include flats and sides was used as a model. In general, underwater bottom systems are replaced at one, two, or three year time intervals but rarely extend beyond two years. Therefore, the age of the system drops out as a variable. It is interesting to note at this point, that a similar number of data points fell within each failure grouping regardless of the exact age of underwater systems as long as the maximum interval was held at three years. The variable, trade route, was not considered because the sampling was taken on a world wide basis. Therefore, performance is being compared on a world wide basis.

Based on the available histories, the following types of antifouling finish coats were considered for evaluation and comparison. Please note that this is not a comparison of all the available types of antifouling:

- Antifouling, Chlorinated Rubber, Copper
- Antifouling, Epoxy, Copper
- Antifouling, Vinyl, Copper
- Antifouling, Other
- Antifouling, Copper/Organometalic
- Antifouling, Resin Soap, Copper

The "Ships Paints Performance - Service Histories Questionnaire" includes ten different percent rating possibilities. For the purpose of this analysis, these ten ratings were combined into three groupings. This grouping helps to factor out possible variations in ratings by different individuals. The three groupings are:

O-10% - Satisfactory
11-25% - Marginal
26-100% - Unsatisfactory

Unsatisfactory systems should be replaced at the earliest convenience due to increased fuel consumption leading to poor economics of operation. Of the systems evaluated, the following results were obtained.

This analysis indicates that on a world wide basis, Copper, Epoxy Antifouling paint systems are the best and Chlorinated Ribbers are the worst. If sufficient histories were available, trade route and/or type of ship could be considered as variables.

Another analysis was performed on the exterior freeboard area. The data bank contained thirty histories of solvent based, (alkyl) inorganic zinc with polyamide topcoats and thirteen histories of a solvent based (alkyl) inorganic zinc topcoated with a chlorinated rubber. Of the thirty inorganic zinc/polyamide epoxy histories, twenty-eight were rated in the satisfactory performance bracket (O-10% failure), one in marginal bracket (15-25% failure), and one in the unsatisfactory bracket (50-100% failure). Stated differently, the inorganic/polyamide epoxy systems performed satisfactorily 93% of the time. The inorganic zinc/chlorinated

rubber system only performed satisfactorily 62% of the time, or eight out of thirteen histories. No positive conclusion can be drawn from these small samples. However, trends are indicated. The wide difference indicates a need for further study.

Another part of this study was a limited test program to verify or support actual case histories. The exterior freeboard was selected as a representative area. This area was chosen because of the availability of the test environment and the potential of collecting adequate numbers of historical data. Solvent based (alkyl) inorganic zinc was selected as the primer because of the extensive use of this material in American Shipbuilding. Five different, well known, commonly used generic topcoats were selected.

It is interesting to note here that on the average, the (alkyl) inorganic zinc, topcoated with a polyamide epoxy, outperformed the same inorganic zinc topcoated with chlorinated rubber. This author does not advocate that inorganic zinc topcoated with polyamides are superior to inorganic zincs topcoated with chlorinated rubber. Sufficient data is not available. But the similarity between actual performance and test data does exist and reinforces the indication for further study.

In addition to indicating performance trends, the laboratory-tests demonstrated that not all paint suppliers are equally capable of formulating and manufacturing all generic types of paint. Some excel in epoxies while others excel in chlorinated rubbers.

Properly designed test programs can screen proposed candidate paints and identify potentially poor performers. The cost of such a test program may seem expensive (approximately $5,000) until it is remembered just how much it costs to replace tank coatings which have failed onboard ship (in the six figure range). It must be stressed that test programs must be properly designed and controlled. Placing steel plates painted with different materials in the steel storage yard, and then checking them at irregular intervals, is not a test program. Service environment, service conditions, type of ship, area of the ship, application methods, etc. must all be taken into consideration. <u>Careful selection of test methods will result in the determination of the best coating systems to meet these variables.</u>

Based on the results achieved and conclusions reached by the project, the following recommendations are offered:

1. Increase the data base of performance histories.
2. Establish a computer software program for life cycle cost evaluation.
3. Establish computer software program for evaluating production parameters for various shipyard operating conditions.
4. Combine life cycle cost data and producibility rankings into a common report for specific cases.
5. Design test programs for various severe ship service areas:
   a. Tanks, Ballast, Fuel and Cargo
   b. Underwater Bottom
   c. Boottop (one test presently in existence)
   d. Decks
   e. Cargo Spaces
6. Initiate studies of planned painting operations.

QC CIRCLES FOR IMPROVING QUALITY AND PRODUCTIVITY

C. Philip Alexander
President
Ann Arbor Consulting Associates Inc
Ann Arbor, Michigan

Mr. Alexander is currently involved in assisting a wide variety of organizations, primarily in the business/industrial sector of the economy, in launching QC Circle programs. He is an active consultant in the field of management and organization development, with expertise in MBO, organizational surveys, planning and problem solving. He is particularly interested in small and midsized firms and consults with a number of CEO.

Mr. Alexander holds degrees from Case Western Reserve University and the University of California.

ABSTRACT

In 1962, the first Quality Control Circle was launched in Japan under the auspices of the Japanese Union of Scientists and Engineers (JUSE). Today it is estimated that one worker out of six in Japanese Industry participates in a QC Circle. The foremost authority in the world on Quality Control, Dr. Joe Juran, estimates that in the first 10 years of the QC Circles movement, the Japanese industry saved an estimated $25 billion. The figure today would be over a $100 billion.

The dollar figures and improvement in quality, however, are only the most visible aspects of what has happened in Japan. The heart of the QC Circle program is a highly trained workforce engaged in identifying and implementing opportunities for improving their own immediate working situation, and the product which they make or service which they provide. This comes about in small groups or Circles of workers which have volunteered to be trained in QC Circle techniques. These Circles select and work on problems or opportunities for improvement, and then with management approval implement them. These small groups of 5 to 10 workers are normal work groups and usually include the supervisor or foreman (who is also a volunteer).

QC Circles as it exists in Japan and as it is evolving in the United States, and other countries around the world, is not another management program. It is a means of changing the focus of an organization from using people to build products or provide services to the opposite; using the problems and opportunities associated with making products or providing services to build people. This focus on building people is the key to its success. And it is successful. In the U.S. over 70 major firms which read like a corporate "Who's Who" have launched successful QC Circle activities since 1972. Once launched by a firm, these QC Circle activities have expanded to other plants.

In Japan, QC Circles are found in every major part in industry and commerce. In the U.S., the involvement has started in the electronics, aerospace and automobile industries and is rapidly expanding to other sectors of the economy. The U.S. shipbuilding and repairing industry is a relative newcomer in the use of QC Circles. Norfolk Naval Shipyard launched the first program in this industry about a year and a half ago. More recently Charleston and Long Beach Naval Shipyards have initiated QC Circle activities.

QC Circles - improving Quality and Productivity by Building People.

1. IntroductIon - Review of topics to be covered and not covered.

2. Definitions and Brief Hlstory
   a) QC Circle
   b) Technique and Philosophy
   c) U.S. lnvention - Japanese Development

3. management Phllosophy and Organlzationl Characteristics
   a) People Building - Solving of problems and achievement of objectives is used to build people rather than using people to solve problems.
   b) Trust Based - Decisions to participate, to support, and to project projects.
   c) Voluntary
   d) Open Communication - Freedom from fear of punishment regarding bad news; All relevant information available and access to sources.
   e) Supportive and committed management - willing to change itself and support others in the process.
   f) Patience - Big nave vs. Tide
   g) Training and Development Orientation - Technical, behavioral and economic with line managers assuming primary role in training.
   h) Focused results - tangible and intangible, to provide feedback for learning.
   1) Policies and Procedures encourage collaboration and cooperation - Organizational structure, reward system.
   J) Management and Union share responsibility

4. Why Choose QC Circles as an approach?

   a) Provides basis for delegating down and problem solving up.
   b) Generates measurable and organizationally important results - quality and productivity.
   c) Requires no radical changes in organizational structure or policies at beginning
   d) Has the support of growing body of union leadership.
   e) Excellent basic building block for long range shift in management style and philosophy.
   f) Creates long term needs for more sophisticated training; more career planning and developments ; smaller support staffs; flatter organizations.

5. Implementat!on of a QC Circles effort.

   a) lop level commitment to philosophy and decision to proceed.
   b) Established of Advisory or Steering Committee
   c) Selection of Facilitator (s)
   d) Orientation and training of middle management and union leadership
   e) Top-down volunteering process to determlne where to launch pilot Circles.
   f) Train supervlsors, Facilitators and others who volunteer to lead or be involved with Circles.

g) Circle leaders train Clrcle member volunteers.
h) Circles work on projects of their own selection
1) Review pilot phase.
J) Expand in an orderly fashion.

6. Videotape presentation - “Quality Circles Case Study”

7. Question and Answer Session

8. Topics I will not cover in presentation but which can be covered in Q 6 A session. If there is interest.

a Differences between Japanese and U.S. Cultures and implication.
b) Results of Circle programs in various companies (except for videotape)
c1 Failures and their causes
d) Factors of timlng and organizational readiness.
e) Compatibility of QC Circles and other programs.
f) QC Circles training techniques
9) Union-Management relationships
h) Review of current literature.

QC Circle implementation - People Building vs. Problem Solving Approaches

There is a question typically raised by managers which goes something like this "Couldn't we use the QC Circle techniques in the Task Forces which we have (or will) set-up? Wouldn't this be an effective way to launch QC Circles in our firm?"

The answer to the first question is "Yes, the techniques can be effectively used by any group of people who are focused on solving a common problem".

The answer to the second question which is some times implled and not clearly stated is "No". And the reasoning needs to be made clear as to why.

Task forces and comrnittees are aImost always set-up to solve or work on specific problems or issues. The primary objective of the task force or committee is, by its very nature, the solution of the problem. Other aspects of committee or task force membershlp take a secondary role. Reference to the accompanying chart, "People Building vs. Problem Solving: A comparison of QC Circles with Task Forces and Committees '' clearly indicates this and the other differences between task force and work group focused teams (QC Circles).

With QC Circles, the primary objective is the development of the individuals In the Circle including the leader. This is accomplished by tralnIng and working on tasks, but that does not detract from its primary emphasis. When the primary objective is the development of people, training and working on tasks should occur in the group where long term relationships are established to provide the necessarv support, help and encouragement.

It is particularly important that these relationships include the supervisor of the group. The reason for this is that the supervisor needs opportunities to learn new ways of being a leader, to shift from the typical task/production oriented approach to a participative/people building approach. in the QC Circle the leader gets imrnediate feedback on his or her own development along these lines.

From this perspective it can be seen that an effective QC Circles program needs to be "anchored" in the organizational structure in normal work groups. These groups may on occasion include individuals with different functional supervisors, but the key to membership in a Circle is a long term working relationship among the Circle members involved in doing a common task or tasks.

Circle members "live" as well as work together in their organizational setting and much of their development relates to improving their relationships by mutual support, help and encouragement. The development in both the areas of relationships and task performance are critical. Neither can be accomplished effectively without the other.

Therefore, in launching a QC Circles program focus it on normal work groups. Leave the expansion of QC Circle technique utilization in Task Forces or Committiees until later when the program is solidly anchored in the organization.

PEOPLE BUILDING VS. PROBLEM SOLVING

A Comparison of QC Circles with Task Forces and Committees

	QC CIRCLE;	TASK FORCE OR COMMITTEE
Primary Objective	Build Circle members .	Solve problem or 1 achieve objective
Participant Selection	Voluntary, both in and out	Usually appointed for term or until project completed
Participant Representation	Usually from same work group	From selected functional areas
Participant involvement	work together full time in addition to Circle meetings	Limited to task force or committee meetings
Leadership	Normal work group supervisor	Leader usually appointed
Skill Level and Training	Skills vary. Training occurs periodically.	Usually highly skilled. No Training.
Project or Goal Selection	Circle members select projects	Problem or objective selected by managemnt
Implementation of Recommendations	Carried out by Circle members with management approval	Usually carried out by others
Termination	Ongoing	With completion of project or term

NEW APPLICATIONS OF INDUSTRIAL ROBOTS TO SHIPBUILDING*

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ABSTRACT

Based on shipyard visits and a review of current ship construction, several new applications of industrial robots to shipbuilding are proposed. Preliminary estimates indicate that the time required to perform certain shipyard tasks could be decreased by 50% to 80% by the addition of various robot workstation concepts. Though control of robot workstations may eventually be integrated into CAD/CAM systems, manual techniques can currently be adopted, permitting a worker to program a robot station. Applications include, but are not limited to:

(1) Use of robots for welding in both fixed shop installations and movable field installations.

(2) Use of robots for flame or plasma arc cutting of irregularly shaped pieces such as profiles.

(3) Use of robots for grinding.

(4) Use of robots for blasting and painting operations, particularly in the shop environment where booths surrounding the equipment can be used to shield other workers and to keep the shop clean.

Although industry is now developing systems for many of these applications, particularly welding, painting, and grinding, additional controls and sensors will be needed to facilitate their implementation in the shipyard. Controls are required to program a robot more quickly to carry out a particular task. Sensors are required to slightly modify the robot's course as workpieces change shape as in welding, for example.

* The work on which this paper is based was supported by the Navy's Manufacturing Technology Program under management of the Naval Material Command through Navy Contract N00024-80-C-2026.

BACKGROUND

Shipbuilding is highly labor-intensive--even more so in the United States than in Japan or Europe. To advance automation in our nation's shipbuilding industry is essential for reasons of economy, health, and national security. Specifically, we need to reduce the rising cost of shipbuilding and improve its quality, decrease the number of undesirable tasks in accordance with OSHA and EPA regulations, and prepare for contingencies in which labor skills could become scarce.

Advanced automation is particularly needed for arc welding, but is also important for other shipbuilding tasks. Since these tasks frequently involve individually made parts, they can be fabricated only through the use of highly programmable automation, which is characterized by flexibility, adaptability, and ease of training. An industrial robot--consisting of an arm, tool package, sensors, and a computer-based control mechanism for training and execution--is a programmable system.

Within the last **15** years industrial robots have been introduced into several sectors of industry to replace human workers performing undesirable tasks--tasks that are harmful, hazardous, strenuous, unpleasant, and dull. The use of industrial robots has yielded 'an increase in both productivity and product quality.

Nevertheless, despite their proven capabilities and benefits, industrial robots are not yet working for the shipbuilding industry. This is primarily because robots are neither mobile nor adaptable to variations in workpieces and the environment; e.g., they must contend with poor fitup in arc welding and variability of assemblies. Another impediment is the substantial engineering research and development work that is required to develop and debug the first robot workstations; capital investment is estimated to be from $35,000 to $150,000 per robot workstation.

Advantages of robot workstations in shipbuilding would be:

(1) Robots can have significantly higher throughput than manual workers because both the duty cycle and power of the tools can be substantially increased.

(2) Improvement in working conditions: machine operators and supervisors will be required.

(3) Increased productivity will alter traditional work methods and attract work to the more productive robot workstations. For example, in addition to doing the customary blasting jobs, a robot blasting center might be used to reduce the manual labor in cleaning welded joints, a task traditionally done by chipping, sanding, and wire brushing.

(4) Dirty jobs such as painting and blasting that would normally not be performed indoors, can be enclosed in dust- or fume-proof booths vented to the outside.

(5) Robot workstations can be introduced to alleviate production bottlenecks or to increase productivity as capital equipment funds are available and return on investment is sufficient.

(6) Robot systems are amenable to CAD/CAM implementation. Cutting, grinding, blasting, welding, and painting programs can be generated interactively by computer and automatically sent to robot workstations.

Technical constraints can be reduced by adding the feature of adaptability to industrial robots by means of sensors and computer control. Development of specially engineered tool packages such as welding head, plasma arc cutting head, or grinding head will permit robots to boost production productivity in many areas. Techniques for faster manual and NC programming will boost production even further. How the technical capabilities can be organized is shown in Figure 1. The realization of these capabilities has been the subject of research and development in programmable automation by the Industrial Automation Group of SRI International [4] and by other institutions **[5].**

Current technical constraints can be further reduced by using semiautonomous teleoperation, a technique whereby a combination of manually and computer-controlled robots is applied. Manual control can be used now before new systems are deployed and available.

Development constraints could be eased if the government would participate. Government agencies such as the Department of the Navy or Department of Commerce (Maritime Administration) might speed the application of robot technology to industry by carefully selecting,

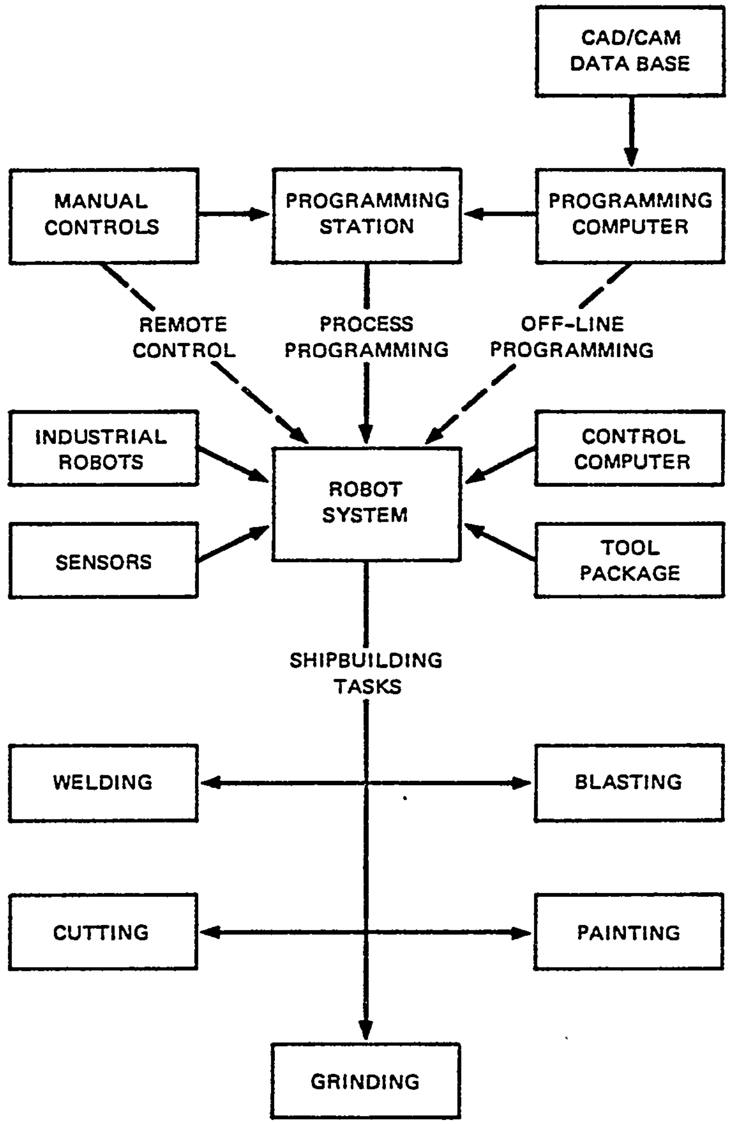


FIGURE 1 ORGANIZATION OF A ROBOT SYSTEM IN SHIPBUILDING

supporting, and monitoring research and development projects. Cooperation among users, 'suppliers, and research and development laboratories would also expedite results in this area.

Supported by the Naval Material Command under technical direction of the Naval Sea Systems Command, the Industrial Automation Group at SRI carried out a feasibility study [1] to examine how shipbuilding tasks are currently performed, to determine which labor-intensive or undesirable tasks can be performed automatically or semiautomaticaly (employing on-line manual control) by robot systems, and to conceptually design such systems.

NARROWING THE FIELD OF SHIPBUILDING TASKS

We studied possibilities of applying robot automation to shipbuilding tasks in several ways. Our approach included a survey of pertinent shipbuilding publications, 12 man-days in visits to several shipyards, and personal communications by phone and letter to shipyard personnel. , We surveyed existing industrial robots and associated equipment, either commercially available or in development stages, that might be used in combination to perform automated shipbuilding tasks.

Two previous studies are-pertinent to this discussion:

(1) A Navy report, entitled "High-Cost Factors of Ship Construction," describes shipyard tasks with associated numbers of man-hours for each task by type of ship. In this report labor-intensive work groups are clearly defined and ranked.

(2) **A** maritime administration report, entitled "Feasibility Study of Semiautomatic Pipe Handling System and Fabrication System," **[3]** present an in-depth application of automation to one of these work groups.

Based on our visits to four shipyards, we identified three work groups amenable to robots:

* Arc welding and cutting
* Spray painting and blasting
* Chipping and grinding.

These three work groups are listed in the order of decreasing percent of man-hours each in Table ,l. Note that welding, the largest group, is broken down into three parts for more detailed analysis.

Table 1

EVALUATION OF WORK GROUPS

Work Group	Man* Hours (percent)	Labor Intensive	Work Environment	Robot Technical Solution	Relative Robot Automation costs
Welding	12.8		undesirable		
Structural	8.3	yes		feasible	moderate
Pipe	3.2	moderate		feasible	moderate
Burning	1.3	no		limited	low
Painting & Blasting	4.5	yes	harmful if unprotected	feasible but limited	low
Chipping & Grinding	2.0	yes	very undesirable	feasible but limited	low

*Based on overall shipyard operation [2].

Our decision to consider conceptual designs for these areas is based primarily on the feasibility of a robot technical solution. Where we judge a solution feasible (even if limited) or low cost, conceptual designs are developed. Automating pipe welding is given only minor treatment here because of its extensive coverage in the Avondale Report [2].

NEW ROBOT SYSTEMS FOR SHIPBUILDING

Using robots in shipbuilding offers two principal advantages. The first one is increased operator factors--the operator duty cycle in performing a given task. A human worker welding, burning, grinding, or

blasting spends only 23 to 30 percent of his time in productive work. A robot system, on the other hand, can perform these jobs continuously.

The second advantage of using robots is the increased tool power. A robot can carry heavier, more powerful, and more dangerous tools than can a human worker. Examples are a 1200-amp plasma arc cutting torch, a 50-hp hydraulically powered grinder, and a heavy-duty slot blast nozzle. Employing these tools at the increased duty cycle, a single robot system Can, in some cases, produce the same work output as perhaps 10 to 30 human workers. Of course, several more highly skilled technicians will be required to set up and program the semi-autonomous robot systems to perform these tasks.

The following sections outline the main advantages of applying robot systems to shipyard tasks. The description of faster robot programming techniques is presented first because it applies to all the subsequent conceptual designs. Unless a robot can be quickly programmed, productivity increases will be limited. Several conceptual designs are suggested for possible application of robots to shipyard tasks. These concepts will require further study and are described in the implementation plan at the end of this paper.

Faster Programming Techniques

Slow and cumbersome programming techniques have been used to train existing robots to handle batches of identical parts. Programming techniques for NC machine tools, on the other hand, have been developed to the point where a single NC part is often less costly to make than one made by hand.

Most shipyard applications require fabrication of only one, or at most, a few identical parts at a time. To effectively employ industrial robots in these situations, programming time must be reduced drastically.

Faster robot programming techniques are described in [1]. These include a control box with proportional joysticks to control the robot,

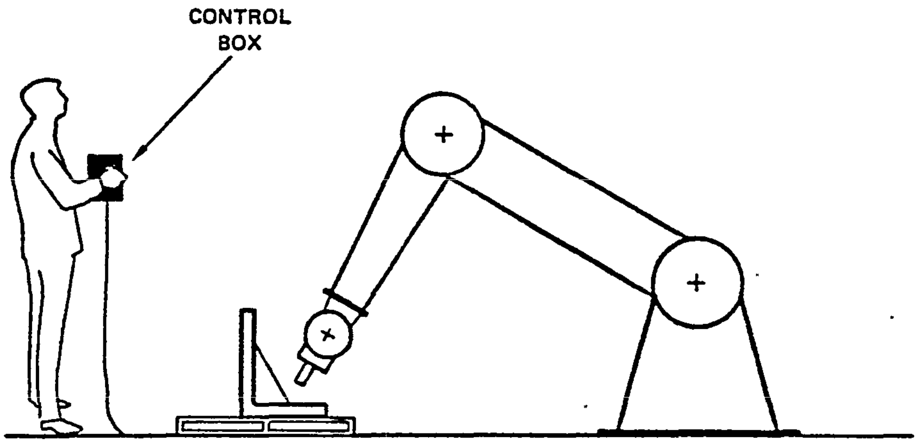
and a separate programming station to manually measure the part and automatically program the robot. Existing shipbuilding data bases may already contain much of the necessary information for CAD/CAM programming. Process modeling, including description of workpieces, robot equipment, and operations, will be required to effectively program robots numerically for single part production.

Robot Welding

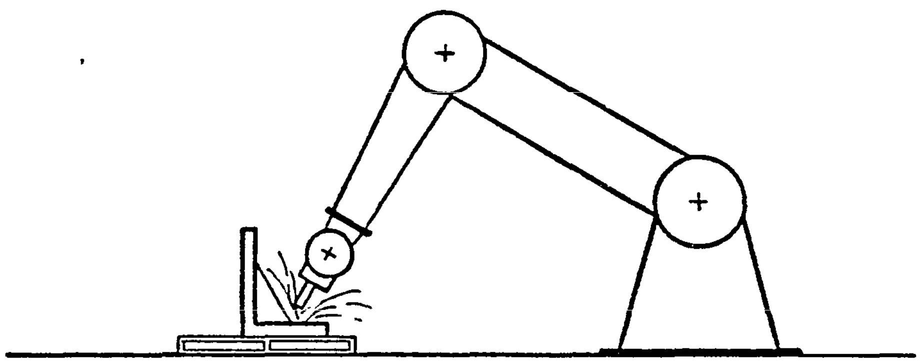
Existing robot equipment is limited in its application to structural welding. Parts to be welded must be cut and jigged to tolerances higher than those economically possible in ship production. Ongoing work is described in [6 to 9]. Precise part fixturing can be eliminated by either manually programming a robot for each individual job or employing NC programming combined with a sensor (e.g., visual sensor) that perceives part fitup variations.

Robot welding can offer substantial cost savings. Anticipated increases in deposition rate (from 2 to 4 lb/hour), operator duty cycle (from 25% to 80%) and productivity factor (from 85% to 98%) may give a system output equivalent to that of 7 men. Robot welding has the added potential for increased uniformity and controllability and decreasing QC costs and rework time.

Using robots for welding could increase productivity by increasing the deposition rate. A robot could move two juxtaposed weld heads along the seam with only slightly increased complexity. Alternately, for some workpieces a two-armed robot system could make two welds simultaneously. Where work is mounted on a positioning table to keep the joint horizontal during welding, a larger puddle can be accommodated and weld current and deposition rate can often be significantly increased (1000 amp). Welding conceptual designs are given in Figures 2, 3, and 4.



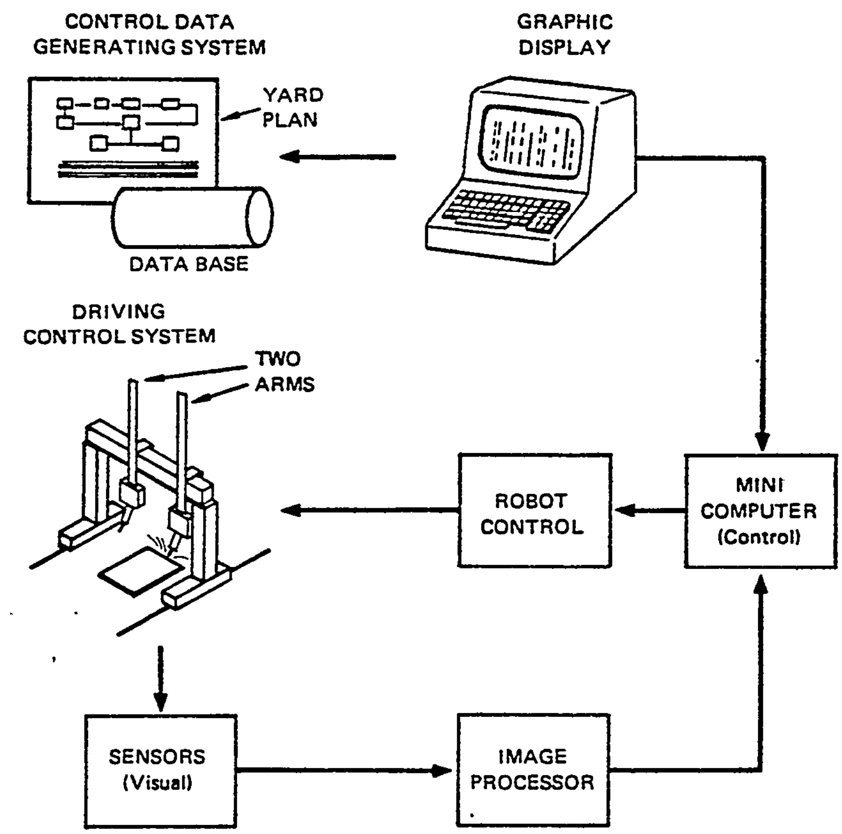
(a) PROGRAMMING A ROBOT FOR PART PROCESSING



(b) ROBOT PERFORMING WORK (SAME STATION)

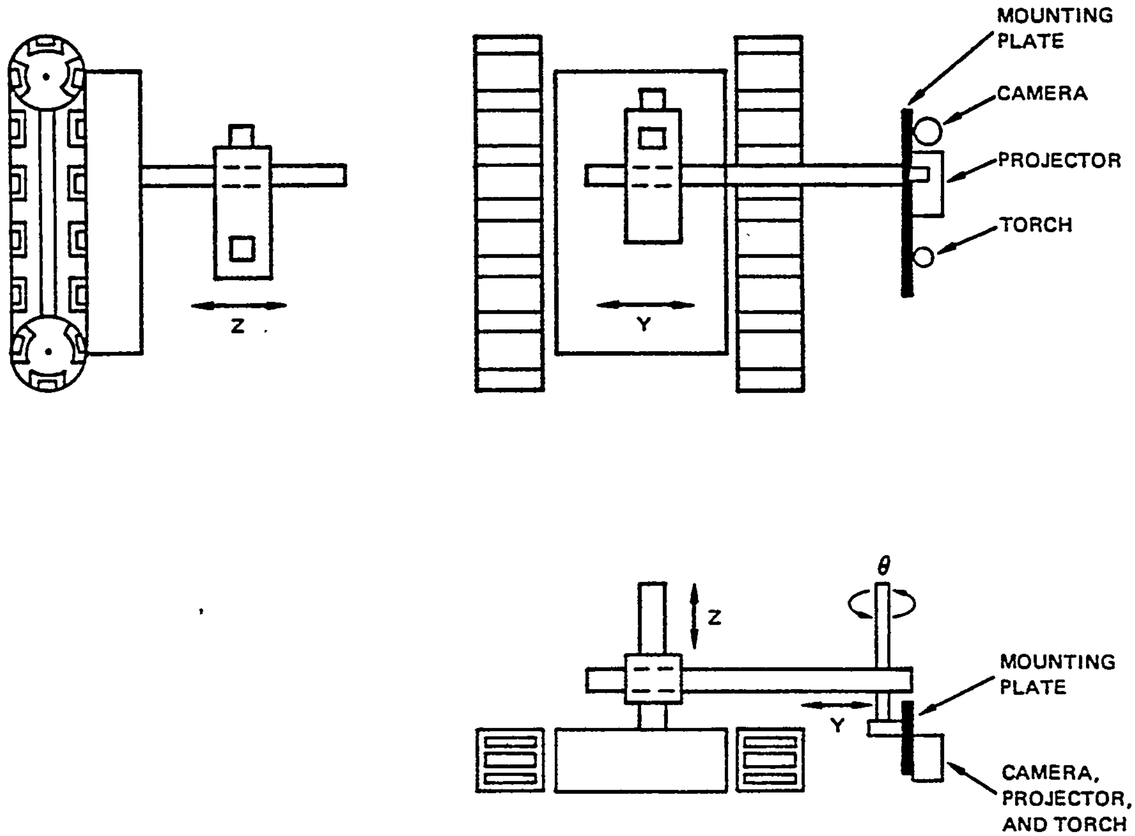
A large, hydraulically powered robot is equipped with a complete welding system (including components such as a torch, wire feed, power, and gas supplies). A workpiece, having been tack welded, is moved to the work station and locked in place. An operator, using specially developed joysticks, positions the weld head at beginning and end points of straight welds to program the system. After programming, the operator turns on the system and assumes a part-time supervisory role during robot welding.

FIGURE 2 FIXED-BASE WELDING ROBOT



An advanced, gantry-mounted, two-arm robot, electrically driven to higher precision than those commercially available, is equipped with dual weld systems. A tack-welded workpiece is moved under the gantry and the robot manually brought to previously defined starting positions on the workpiece. The operator turns control over to a DNC system for controlling the rest of the process. A visual sensor integrated into the weld head enables the unit to locate precisely and follow a variety of joint shapes, including curves. Part-time supervision by the operator is then required.

FIGURE 3 ADVANCED FIXED-BASE WELDING ROBOT



A miniature, tractor-like vehicle is outfitted with a weld system as previously described for the welding robot. An umbilical cable supplies weld and magnetic-track currents, gas, and feed wire to the vehicle. Powerful electromagnets hold the vehicle to the deck, possibly permitting vertical climbing. A visual sensor enables the unit to accurately track various joint shapes once it has been positioned over a seam. As the vehicle moves, a small three-axis manipulator holding the weld head provides the weave pattern and fast corrective movements. The operator positions the unit at the beginning of the seam, turns it on, and supervises.

FIGURE 4 ADVANCED PORTABLE WELDING TRACTOR

Robot Cutting Systems

NC burning tables are now used to flame and plasma cut shapes from flat plates, and computer aids are available to nest parts for maximum stock utilization. NC techniques have also been employed to cut intricately shaped pipe ends and cutouts to fabricate pipe spools.

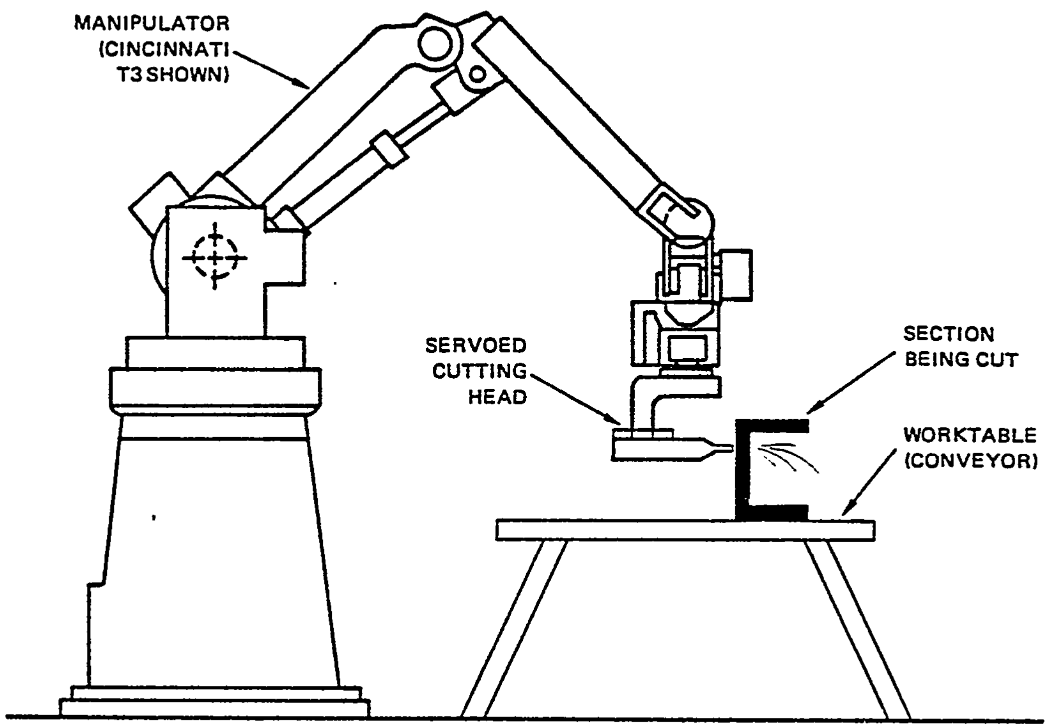
Many irregularly shaped parts cannot be cut with either of these existing NC machines. Of particular interest are long profile sections such as I-beams or T-stiffeners. A frequent problem in cutting these shapes by hand is inaccurate cutting with its resulting repair and rework.

Robot cutting systems offer the potential for substantial cost savings [l]. Mechanized robot cutting offers the advantage of increased speed because high-current plasma arc cutting (PAC) can be employed. PAC could be 10 times faster than oxyfuel flame cutting (OFC). Cutting time (operator factor) is expected to increase from 25% to 80%. These two factors alone could account for a system output equivalent to that of **30** men. Robot cutting also has the potential for uniformity, accuracy, and controlability. Multiple cutting heads further increase productivity. Single and multiple robot cutting concepts are described in Figures **5** and **6.**

Robot Grinding Systems

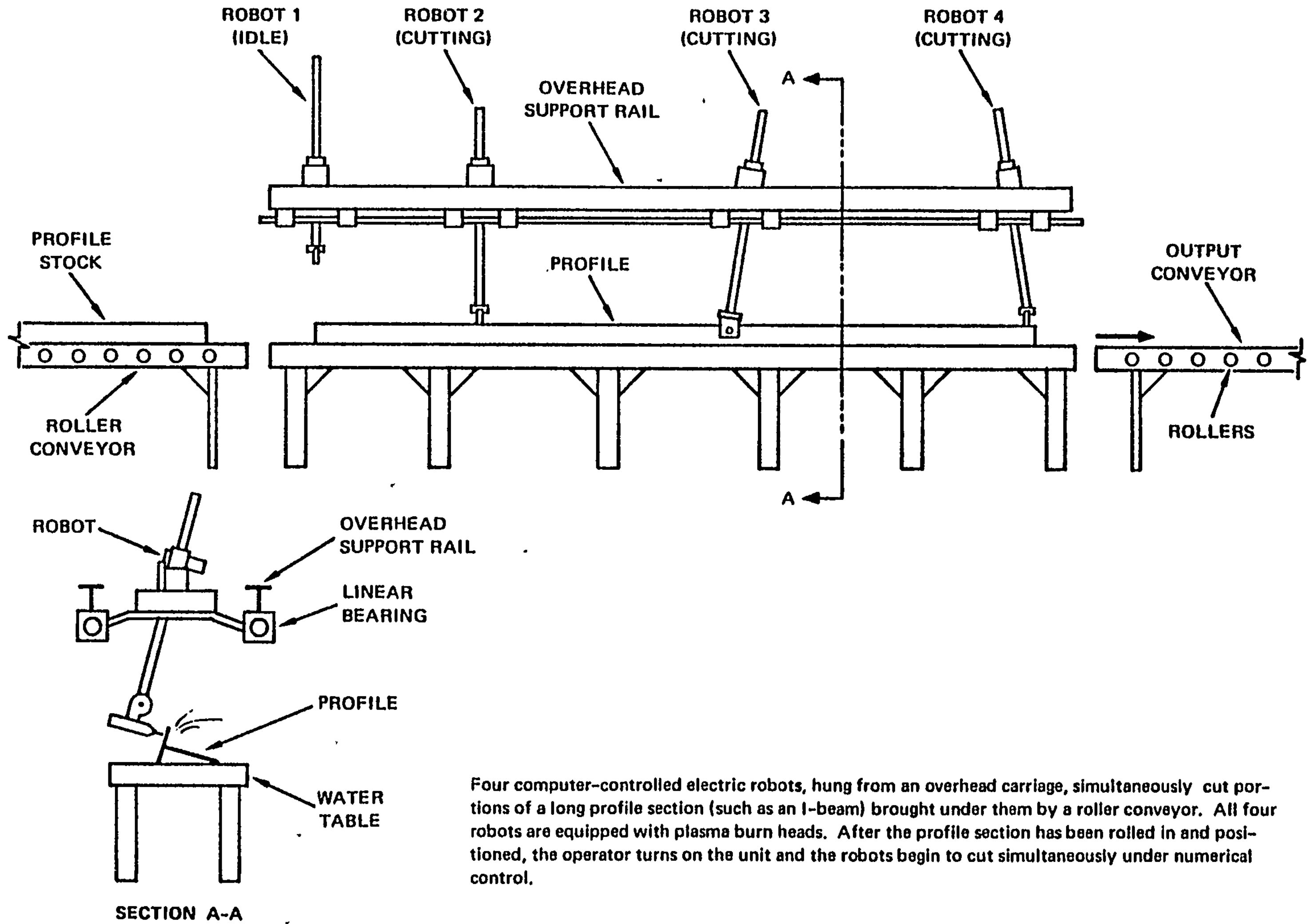
Both heavy grinding, where large amounts of material are to be removed, and touch-up grinding, where slight imperfections are smoothed, were observed in our shipyard visits. Portable grinding tools are limited in power and weight.

An industrial robot can be outfitted with heavy-duty grinding equipment to perform many of these tasks [IO]. In this case the force applied can be increased considerably because robots can continuously handle tools weighing **50** to 100 lbs.



A large, hydraulically powered robot is equipped with a complete burning system, preferably plasma arc cutting (PAC). A workpiece is brought to the station and fixed in place. An operator using joysticks moves the robot to touch cutting lines marked on the part. Once the cutting path has been taught, the operator starts the unit and supervises its operation.

FIGURE 5 FIXED-BASE CUTTING ROBOT



Four computer-controlled electric robots, hung from an overhead carriage, simultaneously cut portions of a long profile section (such as an I-beam) brought under them by a roller conveyor. All four robots are equipped with plasma burn heads. After the profile section has been rolled in and positioned, the operator turns on the unit and the robots begin to cut simultaneously under numerical control.

FIGURE 6 ADVANCED FOUR-ROBOT PROFILE CUTTING STATION

Robot grinding systems offer the potential for large cost savings [1] Robot grinding can be compared to swing-frame grinding: higher grinding pressure and harder abrasive material can be used. Mechanized grinding offers the advantages of higher material removal rates (10 times higher than manual), and grinding time (duty cycle) is expected to increase from 25% to 80%. These two factors can account for a robot system output equivalent to that of 30 men.

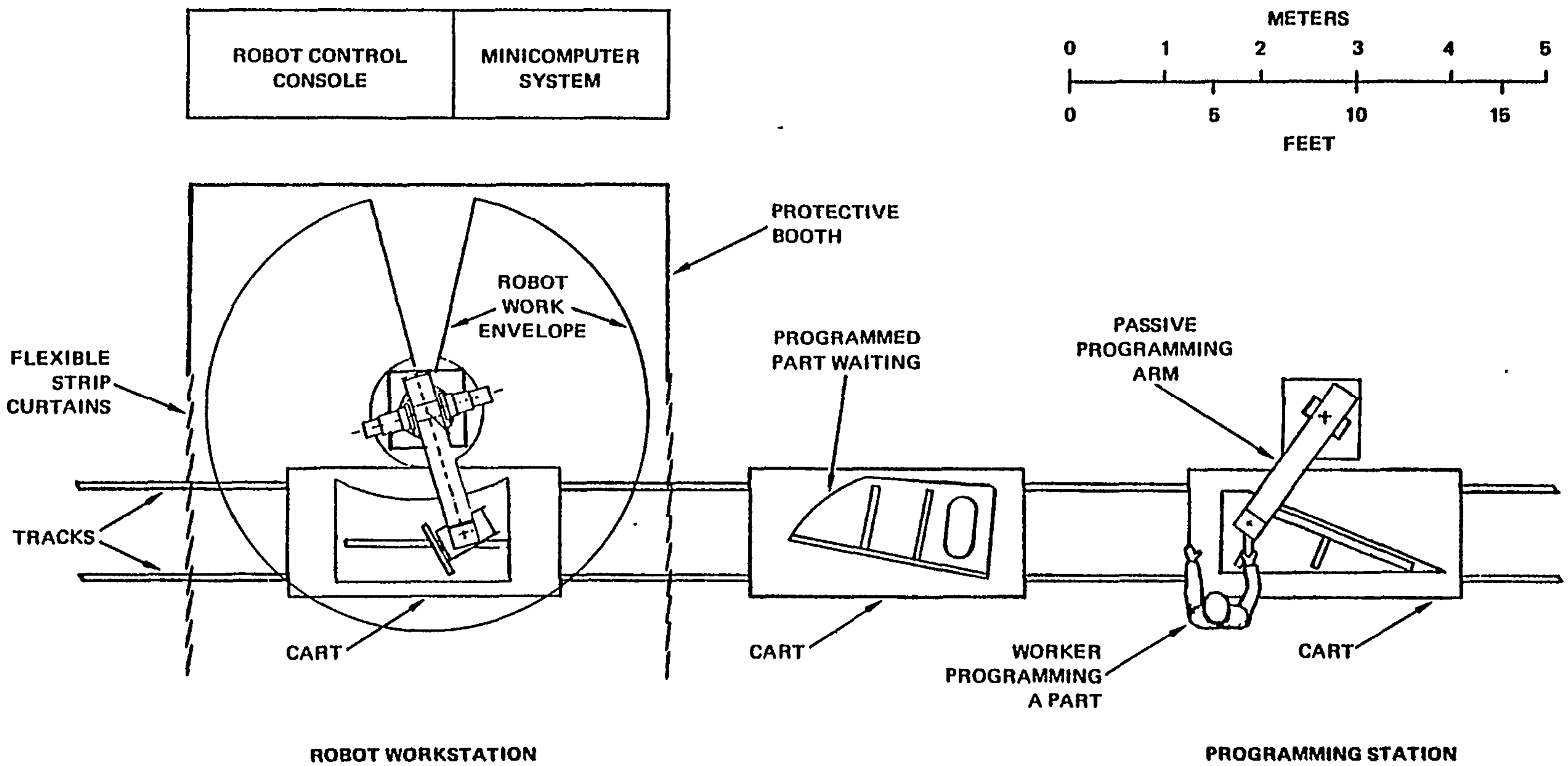
Higher metal removal rates offer an interesting alternative to other forms of metal removal. For example, edges of parts cut from plate or profile, which must frequently be flame-beveled, might be coarse-ground-beveled faster. A robot grinding station concept is presented in Figure 7.

Robot Painting/Blasting Systems

Compared with other robot applications in shipbuilding, these applications would be important for many factors other than economic. Painting and blasting work is dirty, harmful, and undesirable. It is frequently done outdoors with protective clothing and respirators that impede work. OSHA and EPA regulations limit the range of paint and blast substances.

Robot painting offers the potential for improved work conditions and cost savings [I]. Mechanized painting has the potential for increasing paint duty cycle from 25% to 80%. Throughput, however, may be similar to human capability unless multiple heads are used. Painting is fast and programming time will be a limiting factor for state-of-the-art designs. The ability to spray more toxic materials may be an advantage.

Robot blasting offers a higher potential for increased productivity and cost savings than robot painting. Mechanized blasting offers the dual advantages of more powerful blast heads and larger, more effective blast material than can be safely applied manually [ll]. Both of these factors together may increase removal rate by a factor of 10. Blasting duty cycle is also expected to increase from 25% to 80%. These two factors could account for a system output equivalent to 20 to 30 men.



A large, hydraulically powered robot with more than 50 pounds lifting capacity moves a high-power grinding head, Workpieces are moved to the robot station and fixed In place, The operator programs the robot using joysticks to indicate the edges and surfaces to be ground and sets the unit in operation. It automatically follows the trained path at the programmed rate, using feedback from a force sensor.

FIGURE 7 FIXED-BASE GRINDING CENTER

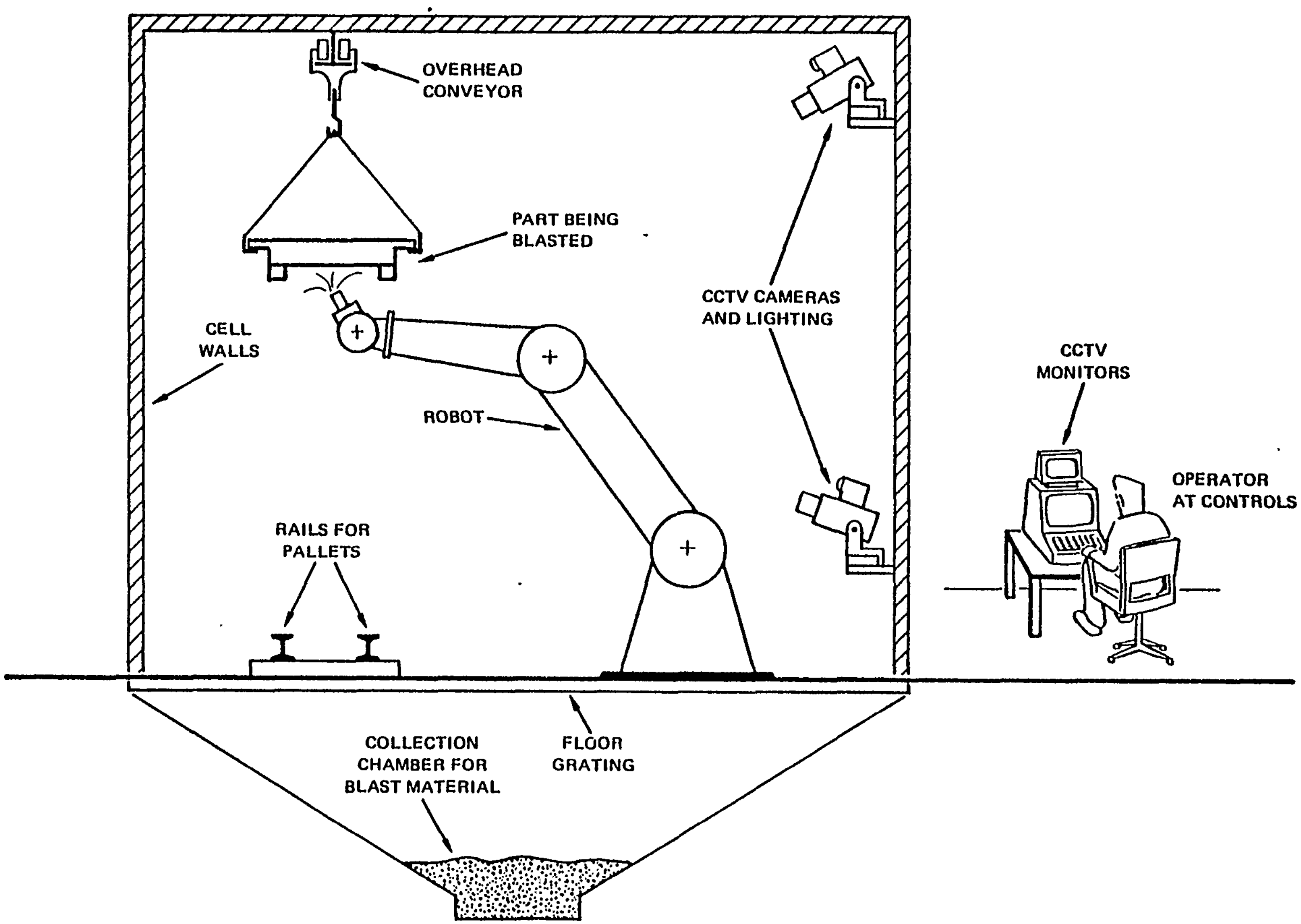
Added advantages of robot blasting are more complete cleaning because of increased velocity and size of shot, applications to other shipyard jobs such as shotblasting welded joints to reduce manual chipping and sanding, and cleaning joints in preparation for welding, ability to install blast cells inside shop areas with ensuing year-round operation, and reduced transportation costs. A robot blasting cell is shown in Figure 8.

Summary of Conceptual Designs

Formulating the required conceptual designs is a complex problem, somehow matching the shipyard needs and the available robot technology. Contending solutions should be flexible, capable of widespread use, highly productive and at the same time low cost, technically robust, and socially acceptable.

Economic factors that bear on the implementation decision are initial developmental and capital expenditures and ongoing operating expenses and benefits (reduction in operating costs and differences in the value of output). Based on simple economic factors, a standardized cost schedule was established for determining the ROI of the conceptual designs [1]. Table 2 summarizes these results. The initial cost includes estimates of robot, support equipment, and installation. Production costs include estimates of system output and charges in the value of the output measured in man-years/year.

Cost analyses indicate that cutting, blasting, and welding tasks are principal candidates for present robot technology. The large increases in productivity possible with plasma arc cutting (PAC) robots give cutting a more favorable initial economic rating than welding. However, six times as many manhours are devoted to welding as to cutting [2], and this unbalance suggests that welding concepts, once implemented, will be put to far wider use than cutting concepts. Attention must be paid, however, to system throughput: robot system capacity (as high as 10-30 men) should not exceed the work available.



A robot arm equipped with a heavy-duty blasting head is mounted inside an enclosed cell having open-floor grating and a recycling system for the blast materIal. A part is brought into the cell on either an overhead conveyor or railroad-type tracks on the floor and positioned in front of the robot, An operator In an adjoining room operates the arm with joystick controls and closed-circuit TV monitors to blast the part.

FIGURE 8 FIXED-BASE REMOTELY CONTROLLED BLASTING CELL

Table 2

COST/BENEFIT SUMMARY OF CONCEPTUAL DESIGNS

Concept	Initial* Cost($)	Equivalent Production Cost (man yr/hr)	Estimated** ROI(%)
Fixed Welding Robot	**123,000**	**3.22**	**34**
Advanced Fixed Welding Robot	**200,000**	**5.85**	**38**
Advanced Portable Welding Tractor	**79,000**	**.67**	**5**
Fixed-Base Cutting Robot	**126,000**	**17.4**	**206**
Advanced Fixed 4-Robot Cutter	**264,000**	**45**	**251**
Fixed Grinding Robot	**130,000**	**15**	**190**
Fixed Remote Blast Cell	**223,000**	**10.5**	**78**

* Initial costs include estimates of robot, support equipment, and installation (rough) cost only. They do not include robot software, factory reorganization, redeployment of workers, or other costs of change.

** ROI figures based on a simplified analysis for comparison purposes [1]. Unknown requirements for additional support operations personnel at higher skill levels will reduce ROI in this table.

Actually, we believe that all the identified concepts are candidates for robot automation. Shipyard management and the Navy must make the final selection based on their own requirements.

SUGGESTED IMPLEMENTATION PLAN

Implementation of any robot concept will require additional study and more refined plans and cost estimates. In any case, more refined conceptual designs will be required before investment in such programs will be warranted by the shipbuilding industry.

Proof of concept work is probably the next step in the implementation of these new conceptual designs. Such a demonstration could be given by a robot manufacturer or by a shipyard with advanced development capability and desire to increase productivity in a particular area. A joint venture between a robot manufacturer and a shipyard might be more successful: the PUMA robot system resulted from a cooperative arrangement between Unimation, Inc. and General Motors. A development contract from the federal government could expedite this process.

General guidelines as to how to define a robot system and demonstrate the concept are given in Table **3.** The items may be applied to the conceptual designs in this paper; additional details for a particular design are presented in the main report [1].

Table **3.**

OUTLINE OF SUGGESTED ROBOT IMPLEMENTATION PLAN

1. Task Specifications

   1.1 Specify tasks by the quantity of each type to be performed by location in a typical shipyard. Labor input is only a rough indicator--footage or parts count may be preferable.

   1.2 Look for other tasks not performed by a robot system that could be more economically done by it, and also tasks that could be funneled through the system to increase productivity.

   1.3 Summarize the quantity of work to be done at suggested installation work sites (number of workpieces, work per piece, transportation means, alternate installation plans, etc.).

2. Detailed Conceptual Design

2.1 Survey the types of robot and support equipment available to implement the conceptual design. Obtain vendor quotes.

2.2 Survey the equipment available for mounting on the end of the robot (workhead) that is applicable to the task considered. Often robot workheads can be made by modifying present shop equipment or semi-automatic workheads.

2.3 Survey types of sensors that are commercially available to monitor proper system operation or to provide the required feedback and control information.

2.4 Develop detailed system concept including robot, workhead, sensors, computer system, software modules, and range of tasks.

3. In-Plant Technology Demonstration

3.1 Develop and build a workhead package suitable for the selected robot, process, and sensor.

3.2 Develop and build a workstation demonstration facility including robot, control, programming, and operation system.

3.3 Demonstrate operation of the workhead package on the workpiece family chosen.

4. Effectiveness Study

4.1 Run timed experiments on candidate workpieces.

4.2 Document performance measurements such as setup time, programming time, speed of operation possible (as ft/min, pounds/hour, etc.), accuracy obtained, quality obtained, problems encountered, throughput (man-hours), operator time (man-hours), system cost, and expected ROI.

4.3 Estimate time and cost of training supervisory and maintenance personnel or retraining existing personnel.

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THE AVONDALE PIPE SHOP: PREPARING FOR PRODUCTION

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PIPE SHOP MANAGEMENT SYSTEM

The Pipe Shop Management System was designed to meet the following objectives:

1) To provide a Manufacturing System that would be tightly coupled with the CADAM System.

2) To provide a total system that would assist in the smooth operation of the Pipe Shop.

3) To provide a System that would increase Productivity in the Pipe Shop and the Avondale functions supporting the production of pipe spools.

To meet the above overall objectives, it was decided, after an evaluation of the functions, that the IBM COPICS software packages would be used. COPICS is an interactive data base manufacturing software system using terminals. Of the available eleven (11) packages, the following were used for their functionality and applicability:

- Bill of Materials Batch Utilities
- Bill of Materials On-Line
- Inventory Accounting
- Advanced,Functions MRP
- Shop Order Release
- Routings
- Facilities
- CORMES

The three (3) packages that are available but are not being used:

- Forecasting
- Costing
- Customer Order

These software packages had to assist Avondale in meeting requirements determined by the feasibility study.

The requirements that these software packages had to assist Avondale meeting, as determined by the feasibility study were:

1) To establish and maintain a current Bill of Material as originated by Engineering.

2) To determine how much material is needed of each raw type on what date.

3) To establish a means to maintain accurate inventories.

4) To produce a process or route sheet for each pipe detail that is to be produced.

5) To Schedule Pipe Details to be produced.

6) To produce a cutting list for Pipe details to be produced.

7) To produce a status of machine loads based on actual schedule of Pipe Details to be produced.

8) To provide location control for Pallet storage.

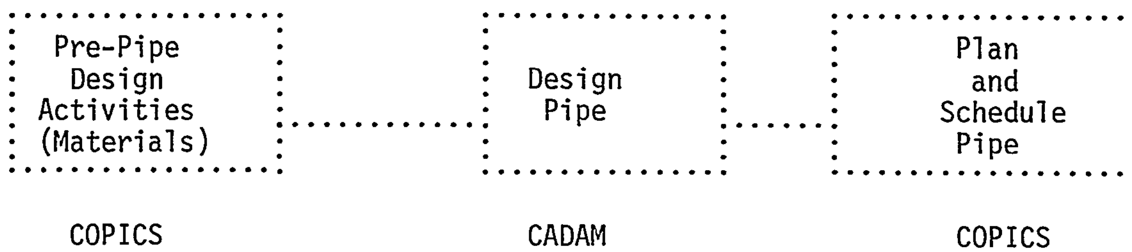


FIGURE A.

The feasibility design of the system, based upon the requirements, was to logically group all activities to be performed (Reference FIGURE A.). Pre-Pipe design activities consists of the requisition and ordering of materials, the assigning of pipe details to pallets, and the determination of the Master Erection Schedule (i.e., when all units, pallets, and pipe details should be complete for erection based upon launch date of ship).

The Design of the pipe is a CADAM function. This function receives input from and generates output to the COPICS system. The Planning and Scheduling of pipe detail is a COPICS function. The activities performed, as well as the everyday maintenance to keep the system in synchronization, is done using the standard COPICS (and in some cases modified) software.

MEETING THE OBJECTIVES

The following narratives describe the system interactions required to meet the three (3) objectives of the Pipe Shop Management System.

OBJECTIVE 1: To provide a Manufacturing System that would be tightly coupled with the CADAM System.

CADAM, the system installed at Avondale to design and produce Pipe Details (PD's), was installed prior to the COPICS decision. The system as installed produced a Pipe Detail and the associated Bill of Material (Reference Fig. 1 & Fig. 2).

Creating the drawing and the associated Bill of Materials has always been defined as an Engineering Function.. However, an additional function was assigned to Engineering to generate and produce data required for the COPICS System: that of creating the Process Plan or Routing for the Pipe Detail through the Pipe Shop.

Creating Routings is one of the functions provided by the COPICS software. However, creating the Drawing on the CADAM System and the Routings on the COPICS System proved akward. COPICS and CADAM are separate systems with no common interfaces. It was therefore decided that since Engineering was to perform both functions, that they would be done on the CADAM System. The results of the plotted output is shown in Fig. 3.

To produce this output, the PD is first generated. After the PD is complete with drawing, Bill of Material , and cut lengths, a menu item is selected to allow for the creation of the Process Plan. This creation is all performed using Light Pen Selection for the routing of each pipe section through the pipe shop for PD completion. The next work station is automatically calculated by the CADAM software. When the PD is plotted, the process plan is plotted also, as if one drawing (Fig. 3).

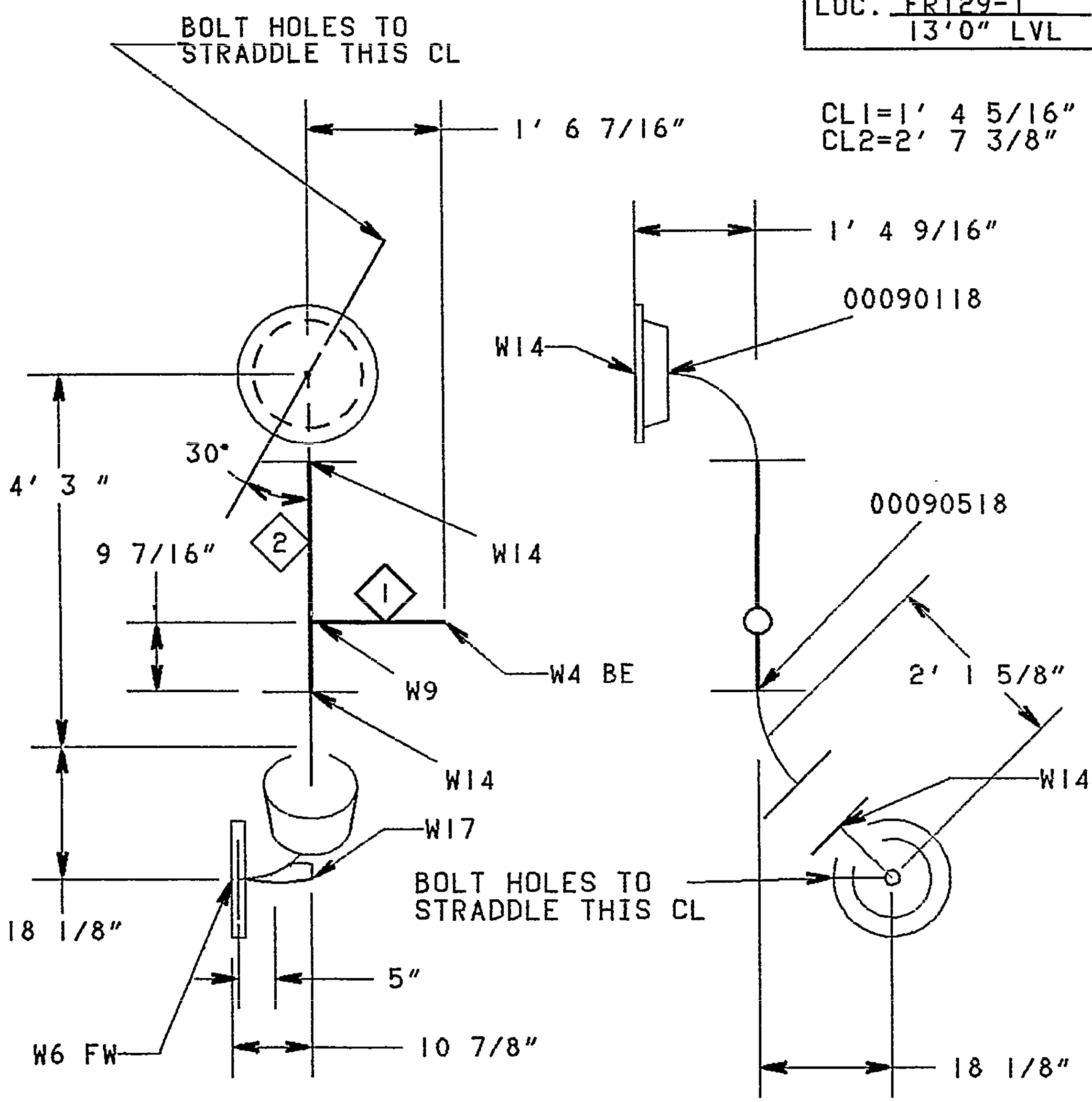
Data required for the COPICS Bill of Material and Routing System has now been created and prepared on the CADAM System. This data has attributes associated with it so that it can be extracted and formatted to be added to the COPICS DL/1 data bases.

Figure B is a graphic representation of this activity. The B/M transactions and B/M Load and Maintenance programs use the existing COPICS code. Routing transactions and maintenance is new code required to update the Routing data base with routings for each PD through the Pipe Shop.

In addition, as new purchased items required for Pipe Fabrication are added to the Product Definition data base through COPICS, they will be extracted and added to the CADAM Pipe Catalog.

FIGURE 1.

P.D.NO. 4-12"
NO. REQD. 1
LOC. FR129-1
13'0" LVL



NOTE: FOR MAT'L SEE
PAGE 8A

COST CODE	AVONDALE SHIPYARDS, INC. P.O. BOX 50280 NEW ORLEANS, LA. 70150	JOB NO. C9-215 DWG NO. 45-006-817 DWN R.L.
	TITLE: MAIN ENGINE L.O. SUCT. STR. & PUMPS PACK UNIT-P/D	REVISION 0

SHEET 8

FIGURE 2.

P.D.NO. 4-12"
NO. REQD. 1
LOC. FR129-1
13'0" LVL

00061318	PIPE STL SMLS STD ASTM A 53 GR B 12
00070117	FLANGE STL SLIP-ON 150 ASTM A105 GR I/II ANSI B16.5 RF 10
00071118	FLANGE STL WELD NECK 150 ASTM A105 GR I/II ANSI B16.5 STD BORE RF 12
00090117	ELL 90 STL BW STD SMLS ASTM A234 GR WPB ANSI B16.9 SR 10
00090118	ELL 90 STL BW STD SMLS ASTM A234 GR WPB ANSI B16.9 SR 12
00090518	ELL 45 STL BW STD SMLS ASTM A234 GR WPB ANSI B16.9 12
00120156	REDUCER STL BW STD ASTM A234 ANSI B16.9 CONC 12 X10
00100950	ELBOLET STL FORGED SW 3000 ASTM A105 GR II 36 -1 1/4 X 1/2

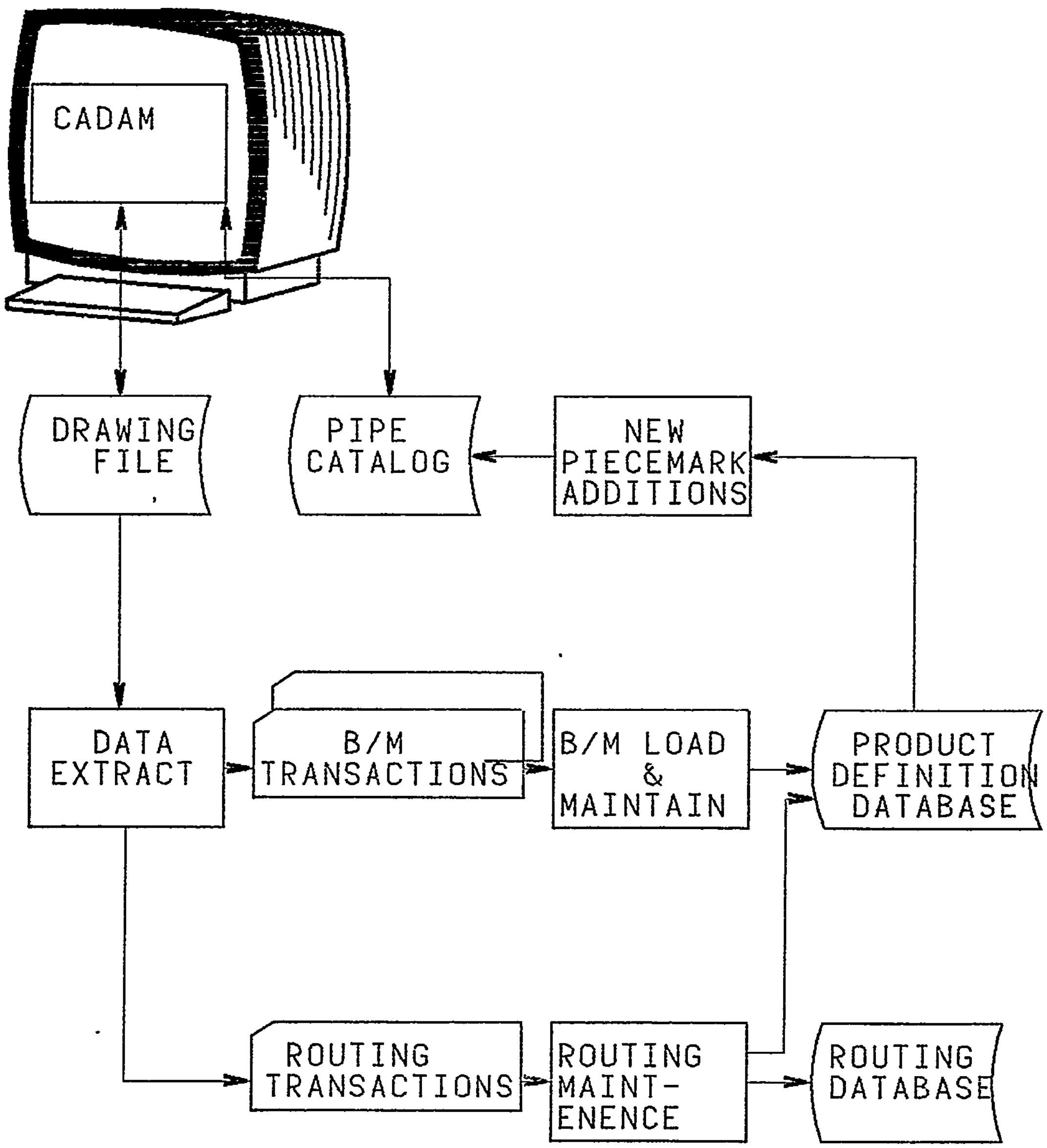
COST CODE	AVONDALE SHIPYARDS, INC. P.O. BOX 50280 NEW ORLEANS, LA. 70150	JOB NO. C9-215 DWG NO 45-006-817
	TITLE: MAIN ENGINE L.O. SUCT. STR PUMPS PACK UNIT-P/D	DWN R.L. REVISION 0

SHEET 8A

FIGURE 3.

10	CLEAN EXTERNAL	1	2
20	CLEAN INTERNAL	2	27
	00090118		
	00071118		
30	SUB SUB ASSEMBLY	27	28
40	SUB ASSEMBLY	28	27
	00061318		
	00100950		
50	SUB SUB ASSEMBLY	27	28
60	SUB ASSEMBLY	28	27
	00120156		
	00071118		
	00090518		
70	SUB SUB ASSEMBLY	27	28
80	SUB ASSEMBLY	28	29
	00100950		
	00120156		
	00090518		
	00090118		
	00090117		
	00071118		
	00070117		
	00061318		
90	X-RAY 1 1/2"-10"	29	31
100	TESTING STATION	31	

FIGURE B.


CADAM
DRAWING FILE
PIPE CATALOG
NEW PIECEMARK ADDITIONS
DATA EXTRACT
B/M TRANSACTIONS
B/M LOAD & MAINTAIN
PRODUCT DEFINITION DATABASE
ROUTING TRANSACTIONS
ROUTING MAINT-ENENCE
ROUTING DATABASE

OBJECTIVE 2: To provide a total system that would assist in the smooth operation of the Pipe Shop.

The standard COPICS System is used to plan and schedule material through the Shop. Some modifications are made to the advanced function material requirements planning system to provide for planning of PD materials by job number. Once the materials are planned, the PD's are scheduled into the pipe shop for fabrication. The Master Schedule input to the MRP run is based upon the following structure:

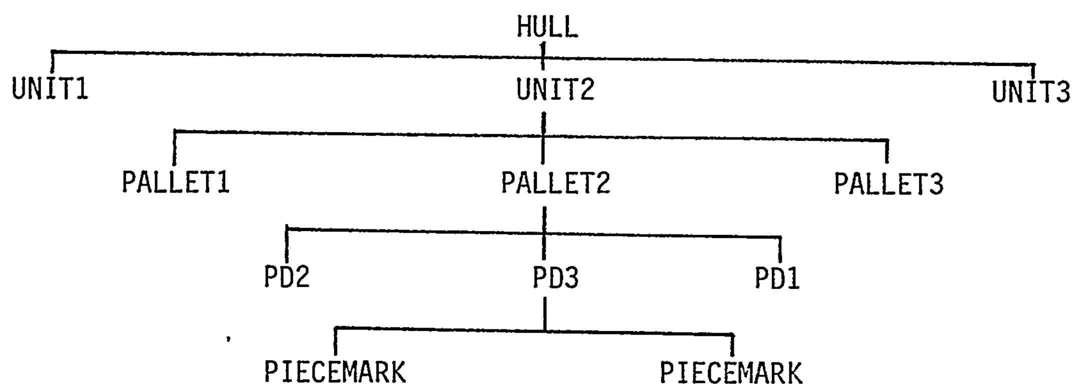


FIGURE C.

The hull and the scheduled completion date are entered into the master schedule. Completion of the MRP Run then establishes need dates for the piecemark or pipe materials. When shop order release is run, shop orders to produce pipe are opened and released and move orders for pallets are issued. In addition, reports will be generated to assist shop personnel in:

- Having material (i.e., valves, flanges, etc.) other than pipe at each work station to complete each days pipe production.

- Having visibility as to the PD's required over a user specified horizon.

- Analyzing shop loads based on PD Production.

- Tracking PD's completed over a specific time period.

- Palletizing PD requirement, and the storage and retrieval of pallets to meet erection schedule.

- Load pipe storage rack to meet daily production of PD's.

- Complete PD's required over a user specified time period (i.e., day, week, month).

Other reports will be generated to al low the shop to know its status each day and what production is required in the future. As time progresses and the reports are used in the production of pipe, a natural progression will be to use the abreviated screens of the COPICS on line system instead of reports to further enhance the operation of the shop.

OBJECTIVE 3: To provide a system that would increase productivity in the pipe shop and the Avondale functions supporting the production of PD.

The primary function supporting the production of pipe is the acquisition of material and to insure its availability prior to production date. One problem associated with using the COPICS software was the start to end cycle and where in the cycle to purchase the material.

The COPICS software assumes the cycle will be as follows:

Create BOM and Inventory Data	—	Master Schedule End and Forecasted Items	—	Plan Materials	-	Purchase Materials	-	Build Product

The Avondale cycle is:

Purchase Materials	Master Schedule	Create BOM and Inventory Data	Plan Material	Build Product

The first cut at material purchase is made very early in the cycle for four (4) reasons:

1) The long lead time associated with some materials.

2) The paperwork involved to produce a purchase order.

3) The paper work flow.

4) The checks and balances imposed on the user to insure that too much material is not being ordered. In addition, all material was being ordered at the same time whether it was needed or not.

The installation of COPICS at Avondale Shipyards provided the following areas of productivity gains in the pipe shop.

The COPICS System for Avondale allows for the creation of a material plan when the requests first exist. However, the material will not be ordered until needed. The material will be monitored against job requirements. When PD's are entered into the System, the material will then be tracked against the PD for the job. By using the facilities of COPICS, the workload to order and monitor the material should be drastically reduced. A 50% increase in productivity in that department would not be unreasonable.

The second area that should experience an increase in productivity should be the production scheduling department. This department expends considerable effort in determining which PD's should be ready when to meet the erection schedule. By adhering to the rules of the master schedule input as shown in Figure E, the prefabrication erection schedule output will be automatic, thus elimination of the manual effort expended to generate and maintain this schedule.

The third area that will show an increase in productivity is that of determining the routing of the PD through the Pipe Shop. By creation of the Routing on the CADAM System and having this routing available at the beginning of the PD production cycle, no special skill will be required on production day to route the PD. Any employee that can read will be able to insure that the PD is routed correctly and fabricated.

AUTOMATED HANDLING FOR FLAME CUTTING

John A. Seelinger
Vice President of Sales
Anderson Engineers Inc
Carnegie, Pennsylvania

Mr. Seelinger is responsible for planning and management of the direct sales efforts of the company, domestically and overseas, for water tables and automated steel plate handling systems used in support of flame cutting operations.

Mr. Seelinger has attended Pennsylvania State University, and holds a degree in business administration and corporate finance from Gannon College.

ABSTRACT

Steel plate handling, in support of flame cutting machines, is usually the major factor limiting the machine's productivity. This is particulary true with the new, faster CNC controlled machines equipped with plasma-arc cutting equipment used in conjunction with water tables.

This paper provides the essential principles and stages of plate handling for a shipyard cutting operation. Typical solutions for both the existing shipyard and the new facility are covered, focusing on the importance of automated equipment to attain maximum production levels and peripheral benefits from today's fast, dependable, and accurate cutting machines. Efficient use of the proper equipment produces cost saving benefits by minimizing labor-intensive stations and providing accurate cut parts to maximize the employment of fixture and robot welding.

Modern flame cutting equipment, incorporating the latest technologies of computer nesting, CNC Control, and the underwater plasma-arc process, delivers dependability and speed. Used in conjunction with a water table, today's cutting operations incorporate several peripheral benefits such as pollution control, quenching of, and ease of handling cutting waste, noise reduction, safety, and above all - improved cut-part accuracy. In one shipyard, the benefits of increased cutting speed and accuracy, from a new CNC controlled underwater plasma cutting operation, saved substantial man hours of cutting, fit-up, and fabrication time on the second of two (2) identical vessels.

Current on-going tests of part accuracy, from various sources, are yet to be tabulated, but initial findings are exciting. Exciting in that all indications point to the ultimate cost-saving benefits by minimizing labor intensive, part cleaning, and maximizing the employment of fixture welding and robot welding.

It is the productivity, accuracy, and the resulting downstream assembly savings that make modern CNC plasma cutting equipment attractive even to the smaller shipyard. Of course, the faster cutting machines must be fed fresh plate and cleared of cut parts more quickly in order to achieve their output capabilities. Just how this plate and part handling is achieved may vary from facility to facility. An operating shipyard with a heavy investment in existing facilities, and limited funds or space for capital improvement, will solve their problem one way. A new facility with adequate budgetary appropriation, eagerly searching for the latest and the ultimate in equipment, may solve their problem in a far different manner.

An analysis of handling starts with examination of product mix, number of plates per hour, per shift, per day, etc.; number of cut parts, crane capabilities, present handling methods, handling speeds, floor space, floor plan, material flow, number of laydown stations, lighting, noise, cut-part routing, cleaning stations, and of course, bottlenecks.

No one solution is sacred. Each application requires analysis of the unique production problems and reduction to a solution that suits your situation best. Two (2) prerequisite goals should be applied:

1. Minimize the number of plate sizes inventoried. Savings generated by volume raw material purchase will help amortize the project.

2. Establish minimum cut-part inventory levels to prevent emergency interruption of scheduled production.

MATERIAL HANDLING SYSTEMS SHOULD ADHERE TO THE FOLLOWING PRINCIPLES:

1. Work should move in an uninterrupted flow.

2. Material transfer time should be low; -never exceeding the processing operation itself.

3. The processing line should be self-sufficient - not requiring external assistance.

4. The process line should occupy a minimum amount of floor space.

5. Material should not be handled more times than necessary.

If we adhere to the five (5) basic principles, listed previously, and focus on an optimum solution to cutting room efficiency - we have to consider the following eight (8) essential stages. Each must be evaluated with an eye toward manpower requirements.

1. Raw material storage may dictate handling methods and access to the cutting area.

2. Raw material staging; -Ideally, there should be a stockpile of horizontally oriented plate, positioned adjacent to the load station or stations in sequence for the work schedule of that shift.

3. Load Station & Load Apparatus; -Should provide the actual loading and squaring of plate while the previous plate is being cut. Full plates should be easily handled with vacuum or magnets on a dedicated handling device which will provide proper plate orientation.

4. The Cutting Station; -Must be accessible for rapid loading without additional lifting or handling. It must be cleared of an infinite variety of cut parts, scrap, and waste and must provide effective and 'complete pollution control.

5. Part & Skeleton Removal; -Should allow cut parts and skeleton (scrap) to be removed rapidly. It is best served by a dedicated piece of handling equipment.

6. Parts Sorting & Skeleton Disposal; -Should be performed nearby and cleared quickly to accept material and allow time exposure for sorting of parts and disposing of skeleton. Delays in processing here can feed back into the cutting process. Handling skeletons in one piece is desirable in many cases. Processing of scrap should be carefully analyzed.

7. Part Cleaning; -In today's technology, good cutting, properly controlled, can deliver virtually dross-free parts. For those parts requiring cleaning, labor intensive cleaning stations should, if possible, be avoided in favor of mechanical cleaning machines.

8. Waste Disposal. Waste disposal should be simple. Waste should not be allowed to accumulate to a point where it affects cut quality or where it becomes a handling problem. Waste disposal should not cause cutting machine shutdowns for extended periods of time.

MULTIPLE TABLE TANDEM ARRANGEMENTS

(Diagram #1)

A multiple table arrangement can increase production by providing multiple plate laydown stations which will enable a single burning machine to operate over one table while plate is being placed on a second, and cut parts and skeletons are removed from a third. This is ideal for heavy plate oxy-fuel cutting and can achieve torch time of 60 - 70% or greater.

Multiple table arrangements can require: 1) a cutting machine operator, 2) a crane operator, 3) a sorter, and 4) a material handler. Each plate is handled multiple times and the cutting cycle is governed to some degree by the handling cycle on an off the table.

TANDEM ZONED TABLE ARRANGEMENT

(Diagram #2)

Operating yards often times find multiple water tables to be an excellent solution. Further, since much shipyard cutting is plate "trimming", and handling involves the movement of either whole plates or large single cut pieces, handling time is usually short and may not exceed the cutting/marking time per station. Here is a solution using two (2) zoned water tables that serve the shipbuilding industry's unique employment of large plate.

The two tables actually can provide either four (4) separately controlled cutting zones to accommodate 20'-0" plus ranges of plate, or two (2) zones (one (1) per table) to accommodate 50'-0" plus length of plate.

IN-LINE PLATE PROCESSING SYSTEM

(Diagram #3)

An In-Line System, which is basically a conveyorized water table, will permit plates to be staged and loaded outdoors or in another bay, thus reducing floor space requirements in the cutting bay. The need for a dedicated overhead crane is minimized or eliminated. Instead, a much smaller crane can be used to load plate which is then passed, by the system, through a narrow building opening into the cutting area. Heat loss is eliminated.

Only two (2) men are required: 1) a cutting machine operator who remotely controls the plate loading crane, and 2) the unloading bridge operator who also remotely controls the pallet carrier for cut parts removal.

The result is a programmed, minimized interval between cutting cycles. Torch time is maximized.

IN-LINE PLATE PROCESSING SYSTEM FOR SHIPYARDS

(with automatic loading and semi-automatic unloading)

(Diagram #4)

The In-Line Plate Processing System can be constructed to accommodate "shipyard" size plate lengths with indexing speed and accuracy to support CNC plasma-arc mirror image cutting and marking. Such a system, in a recent analysis for a customer in the shipbuilding industry, with a cutting program of approximately 7.5 minutes per pair of plates, was shown to deliver 71.4% cutting time. With plate marking included as productive time in the cutting cycle, near 80% production time was reached. Loading and unloading take place within the cutting/marking cycle. Dual plate staging and dual cut-part stations are illustrated. The manpower requirement remains at only two (2) men; -a cutting machine operator who also remotely controls the loading crane and an unloading bridge operator who controls both unloading bridges.

IN-LINE PLATE PROCESSING SYSTEM - ELEVATION

(with semi-automatic unloading for small parts)

(Diagram #5)

Attention is called to the elevation view which helps explain the unloading sequence.

The unloading bridge carrying the unload operator, and equipped with a trolley and magnet assembly, is followed in very close proximity by the pallet carrier; remotely controlled by the same operator. Cut parts are magnetically lifted by the unload bridge and placed on the empty pallets on the pallet carrier. When the pallets are full, the pallet carrier moves to the extreme end (right) where it is accessible for unloading.

In a 5000 random cut-part study of an actual manufacturing situation, unloading was completed at the average rate of 6/lOths of a minute per part; -well within the average cutting time per piece in that sampling. Therefore, typically, the automated unloading cycle can be accomplished within the cutting cycle.

CONCLUSION

Analyze several systems. The optimum system should have a high throughput rate to justify to the initial investment. It is difficult to justify the expenditure for NC controlled plasma-arc equipment without marrying it to equipment that provides rapid indexing of plate and rapid handling of cut parts and scrap to achieve the high productivity and favorable economics that the plasma-arc process is capable of delivering.

Although there may be more than one answer in any given operation, if the homework is done well, it is not difficult to decide on the proper cutting process. By adhering to the basic handling principles, it is not difficult to wind up with a plate processing system that will enhance that cutting process, provide a handsome payback on the total investment in a minimum of production time; -and provide reasonable growth well into the future.

3 TABLE TANDEM ARRANGEMENT

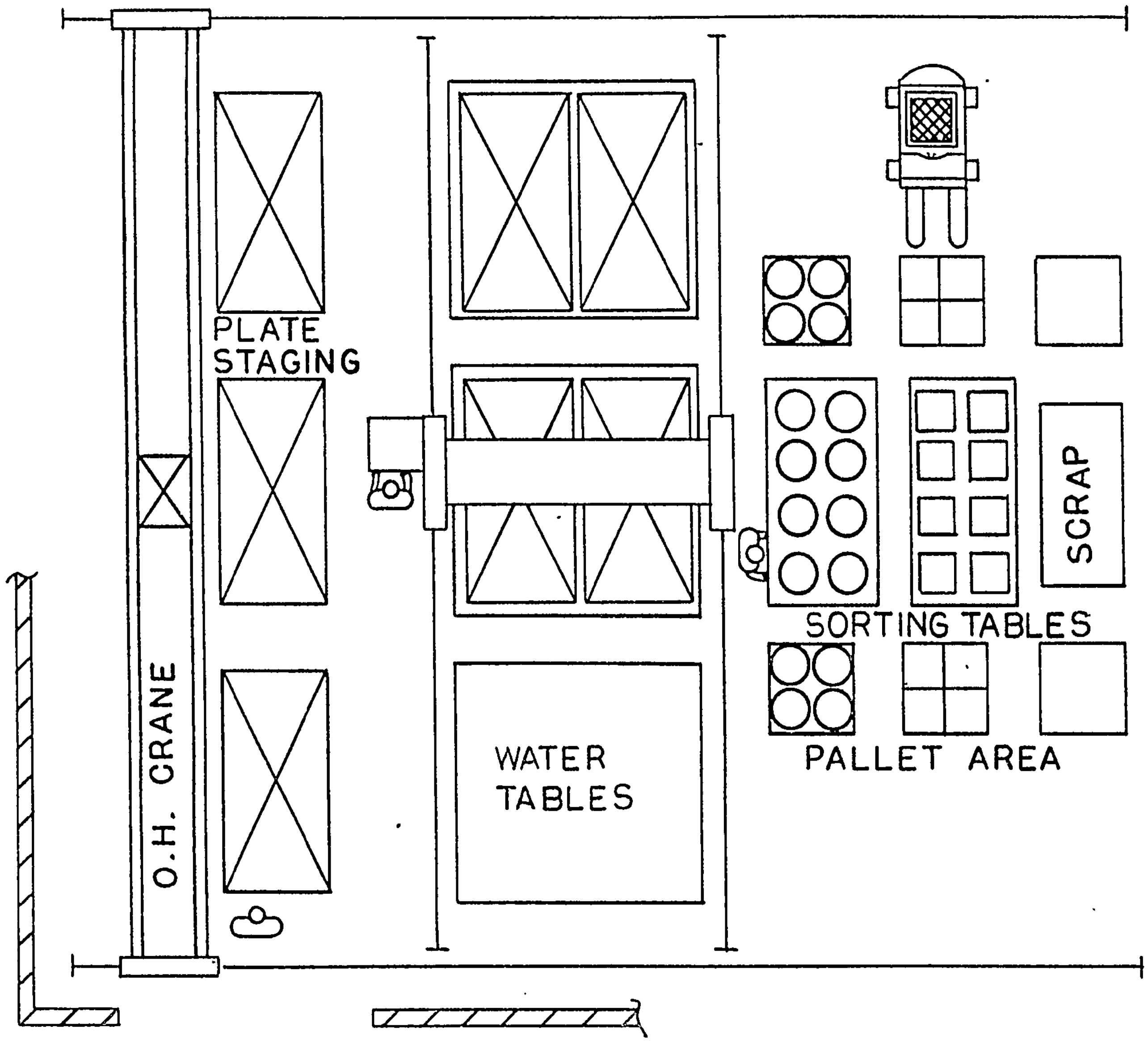


Diagram #1

TANDEM ZONED WATER TABLES

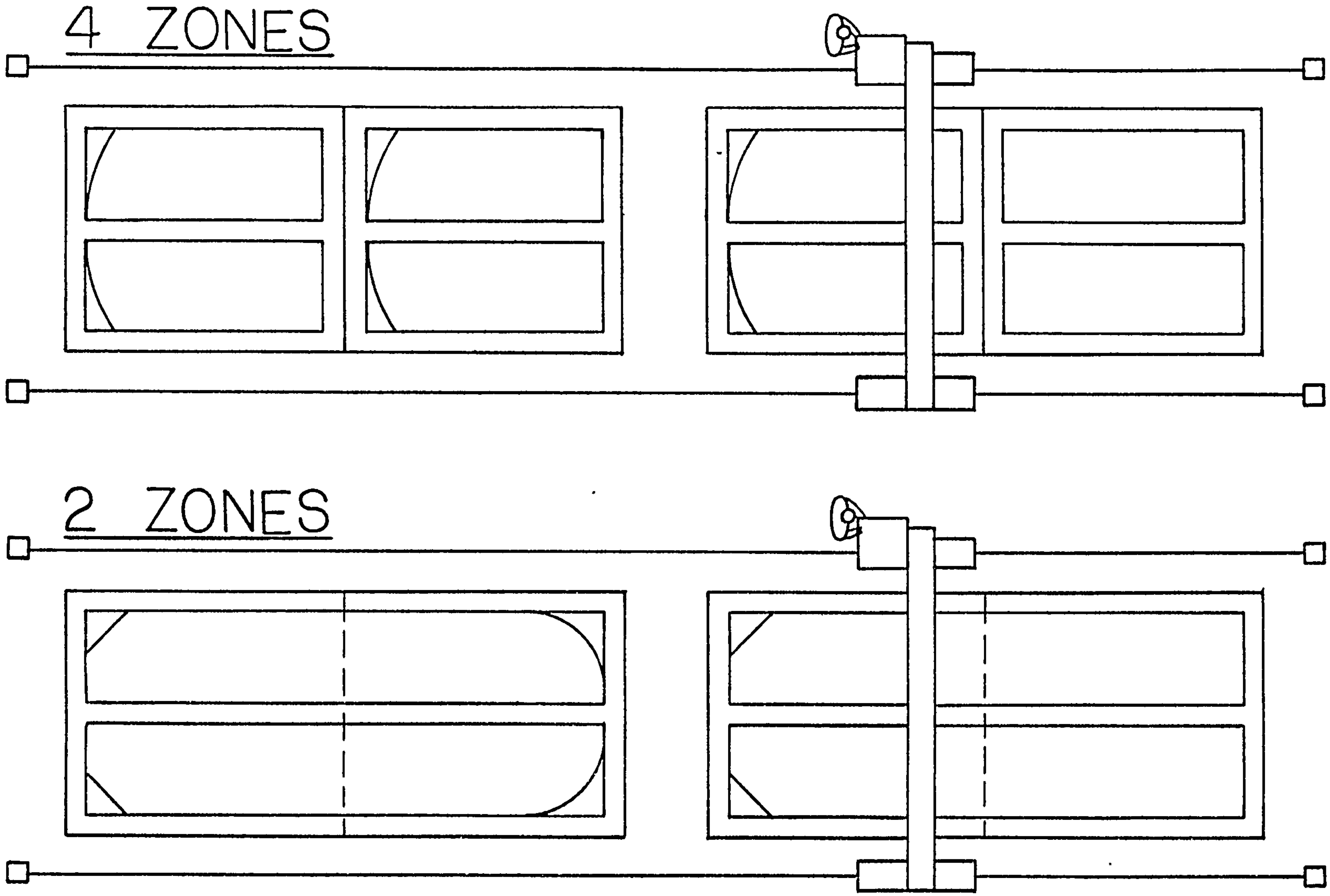


Diagram #2

IN-LINE PLATE PROCESSING SYSTEM

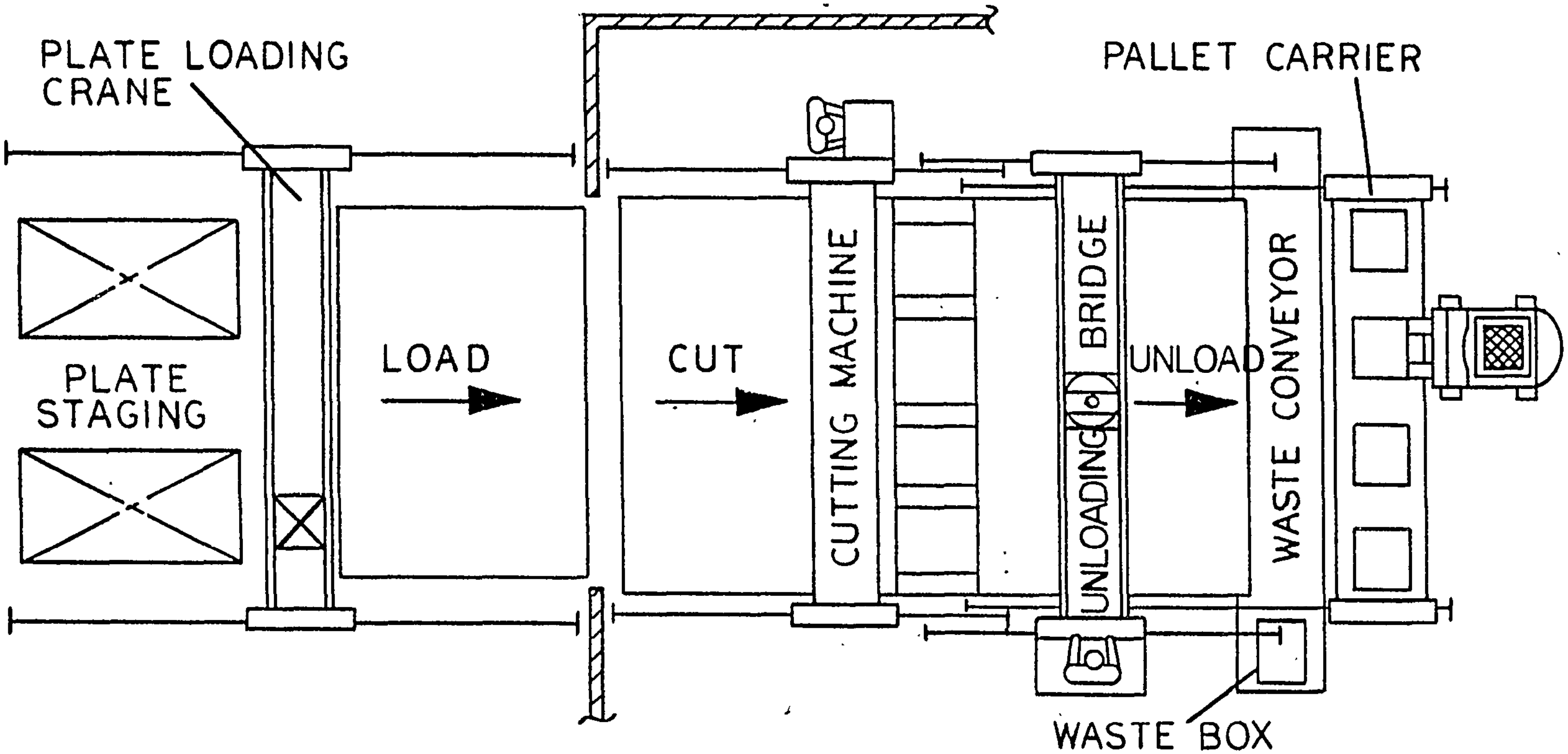


Diagram #3

IN-LINE PLATE PROCESSING SYSTEM FOR SHIPYARDS {WITH AUTOMATIC LOADING AND SEMI-AUTOMATIC UNLOADING}

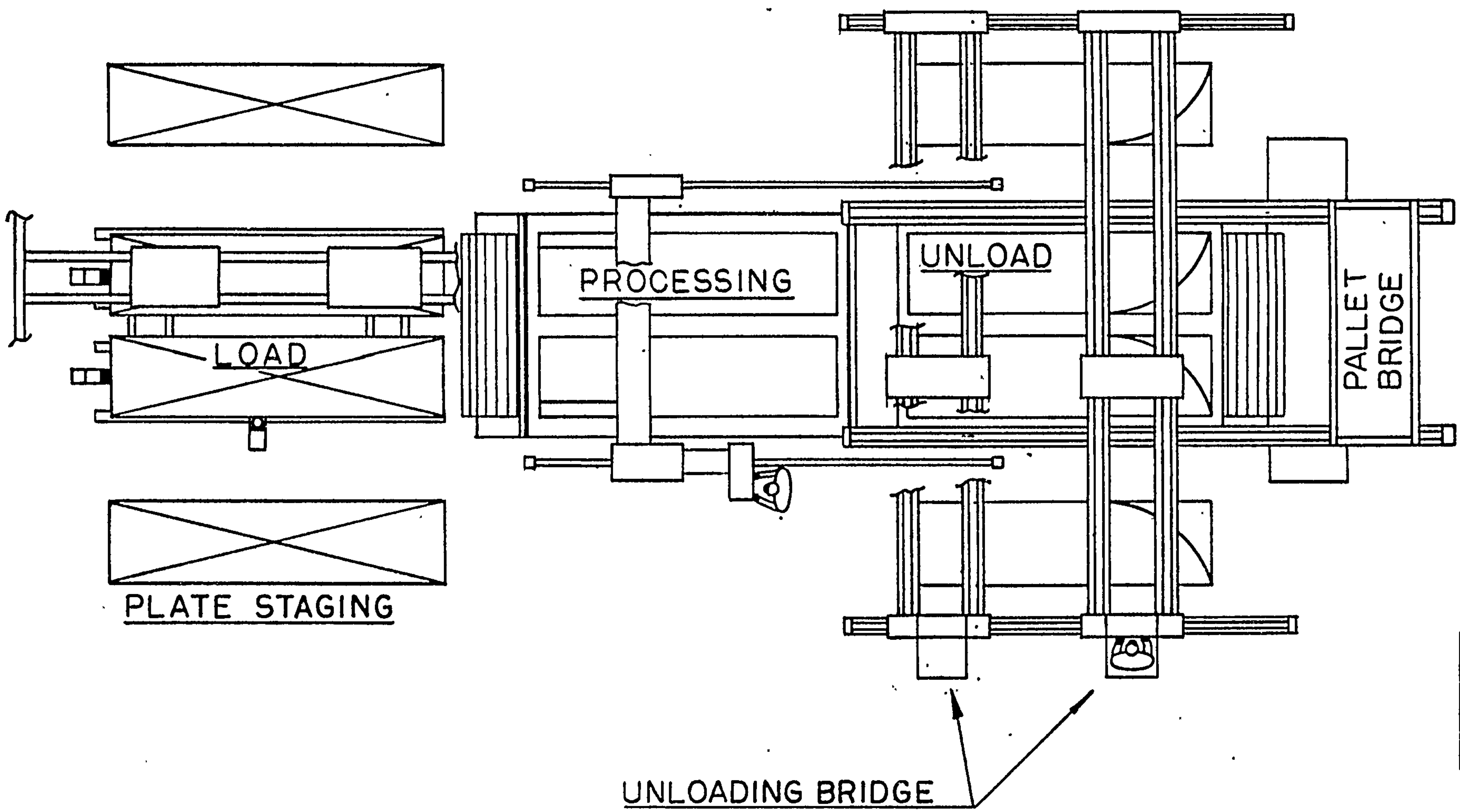


Diagram #4

IN LINE PLATE PROCESSING SYSTEM (ELEVATION)

WITH AUTOMATIC LOADING AND SEMI-AUTOMATIC UNLOADING FOR SMALL PARTS

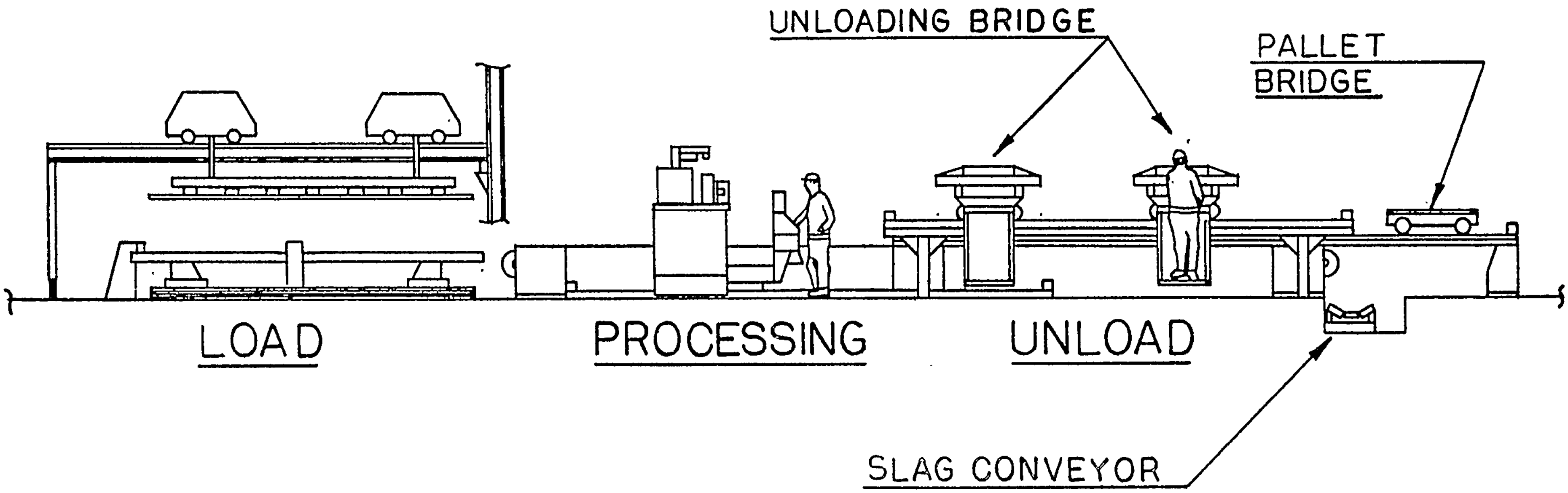


Diagram #5

DEVELOPMENT OF EFFECTIVE COMPUTER CAPABILITIES BY THE J. J. HENRY COMPANY

W. Barkley Fritz
J. J. Henry Company Inc
Moorsetown, New Jersey

Mr. Fritz has been a long-time participant in the computer field having been employed in computer-relatedfunctions with the U.S. Government, Westinghouse Electric, and Sun Ship Inc before joining J. J. Henry Company in May 1980 where he heads the engineering computer operations at their Moorsetown Division.

Mr. Fritz holds degrees in mathematics from Loyola College and Johns Hopkins University.

ABSTRACT

On April 2, 1980, the J. J. Henry Company, Inc signed an agreement with Cali & Associates to use the SPADES system of computer programs to enhance its preliminary contract and detail design service for its clients. As a design agent for the shipbuilding industry, J. J. Henry has been making use of computers for many years; however, this latest step involves a major extension of its production services to computer-aided design.

The paper briefly discusses the new SPADES service, the facilities installed, the training required, and the problems in getting the new service into full production on a very tight schedule. Also included is a listing of the application programs available via its terminal facilities using a variety of off-site computer network services.

Introduction

J. J. Henry Co., Inc. has been making use of the digital computer as an important tool in support of its services to the nation's shipbuilding industry for a number of years. However, in May of this year it took a major step toward the growth of that computer usage by formally establishing an Engineering Computer Operations Department and directing the new Department Head as follows:

1) assist all other Departments in implementing more effective computer-aided design techniques,

2) coordinate, expand and improve our overall computer capabilities, and

3) assist our production services function in achieving the benefits of the SPADES computer programs as a major tool in our design and production services.

This paper covers briefly what has transpired during the nearly 6 months that have elapsed since the new Department was created.

It should be noted at the outset that although J. J. Henry has offices at a number of locations throughout the country, this new committment to computer-aided design is at its major production office in Moorestown, N. J., here in the Philadelphia metropolitan area. At Moorestown, J. J. Henry produces a complete range of design and engineering services to marine and industrial firms. As of this writing, the Moorestown office employs a staff of 226 individuals not including the headquarters financial staff which, although housed at Moorestown, reports directly to the VP for Finance in New York City.

Other smaller J. J. Henry offices are located in Arlington, VA, Portsmouth, VA, Cohasset, MA, and Houston, TX. Area representatives are stationed in Cleveland, OH, and Los Angeles, CA. The company is headquartered at Two World Trade Center in New York City.

J. J. Henry has in the past used interactive, 300-baud terminals as the major means for accessing computer programs at several off-site network computer services; however, to provide the new on-line interactive computer service using SPADES, it has been necessary to expand our computer and data communications facilities by a significant factor.

The balance of this paper covers the nature of the SPADES system as used by J. J. Henry at this time, the new facilities that have been installed, the training completed to date, some of the problems resolved in the start up, and at the close of the paper, a brief listing of a number of computer application programs in use.

SPADES

The key to the new emphasis on computer-aided design is the Ship Production And Design Engineering System known as SPADES. On April 2, 1980, J. J. Henry signed an agreement with Cali & Associates acquiring the right to use major portions of the computer-based SPADES system. J. J. Henry personnel have been instructed on how to enter data into the system beginning with the use of the major computer program designated HULLOAD. HULLOAD enables our personnel to generate computer-oriented descriptions of hull structures and related design data. These descriptions are stored in the Ship File within the host computer and provide ship design data for later use in the Detail Engineering Module (known as DEMO). The DEMO module is being used at present to generate background drawings for a new detail design effort on the LSD-41, as well as to define structural details such as holes, stiffeners and butts. (The LSD-41 is to be constructed by the Lockheed Shipyard in Seattle, Washington.) The use of DEMO also provides a check on the content of the developing ship data base by making drawings of details as they are loaded into the computer. DEMO makes use of a

major portion of the SPADES' PART-GEN program to develop the flat plate parts needed in the construction of the hull of a ship. In addition to HULLOAD and DEMO, SPADES as used by J. J. Henry also includes major modules for FAIRING and HULL calculations. To date, HULLCAL is being used, but the LSD-41 hull itself was FAIRed by Cali personnel.

As most of you already know, the software for the SPADES computer system as developed by Cali & Associates is maintained on a PRIME 750 digital computer at their location in Metairie, LA. J. J. Henry personnel now make use of that system via terminal equipment recently installed in the new computer room located at our Moorestown office. The data to be entered into the system is prepared on the SPADES System Input Data Form. Data from these forms is copied into the computer data base - the Ship File - using any one of the four on-line terminals.

The major advantage to a design agent in using a data-base-oriented, computer-aided design system such as SPADES is the resulting capability to gradually develop in a machine-processible format a continually more complete and accurate representation of the ship design as it advances through the design and production stages of a contract. With relatively simple but powerful commands, portions of that file can be accessed and drawings automatically plotted as required at any stage of the process.

But that is enough for now on SPADES itself. The system has been under development for many years and has been widely reported by REAPS. Suffice it to say that J. J. Henry selected the SPADES system and the computer service approach developed by Cali as a major tool to enhance its capability to satisfy the ship design and production needs of its clients. Fil Cali will discuss the computer-sharing concept by designers and shipbuilders in the next paper on today's program.

Facilities

At last year's REAPS Technical Symposium, Bill Shipley of Marinette Marine and Fil Cali discussed the hardware required to provide N/C processing for a small shipyard. Much of that same kind of equipment is now in use at J. J. Henry except that since we are not a shipyard, we do not need the equipment required for a plate burning center or a plate shop office.

The J. J. Henry computer facilities for engineering are housed in a single room, 19' x 24', with large glass viewing windows on two sides. To cut down on equipment noise, the floor of the room is covered with static-resistant, wall-to-wall carpet and the walls and ceiling with acoustic tile. A separate air conditioning temperature control is available, but no humidity control is provided nor is there any indication of a need for such a control.

The computer room is used both as a computer operations center and as a computer-user training room. The equipment used to access the off-site computer includes 6 computer terminals plus associated data communications hardware as shown on Figure 1.

The terminal equipment assigned to the use of SPADES includes a high-speed, upright, drum-belted Calcomp 960 plotter with a 909 controller (containing a microprocessor and two floppy disk storage devices), two DEC LA 120 printer terminals and a DEC VT 132 alphanumeric video terminal. A dedicated 9600 baud data communications line, multiplexor, and modem connects this equipment to the host computer.

The baud rates used for communication to the host computer are limited by the 9600 baud Bell System line, the capability of the multiplexor, the capacity of the host computer and the characteristics of each terminal. With respect to

TERMINALS

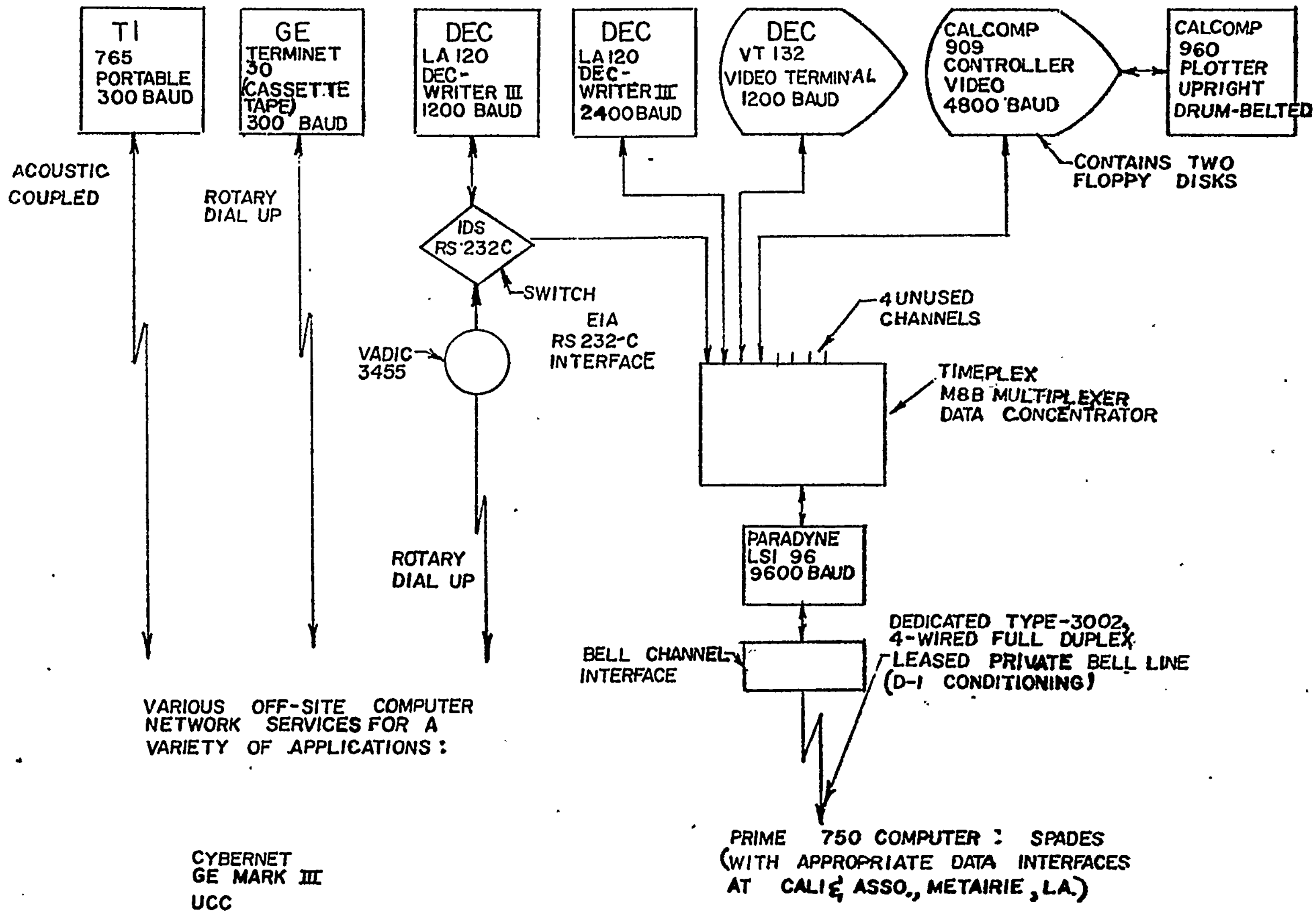


FIGURE 1: ENGINEERING COMPUTER FACILITIES—J.J. HENRY—MOORESTOWN, NJ

the communications network, the Timeplex Model M8B is an 8-channel unit in which channels 1 through 4 are each capable of operating at speeds up to 4800 BPS and channels 5 through 8 are each capable of operating at speeds up to 9600 BPS. The aggregate input limit is 57,600 BPS (i.e., 4 x 4800 + 4 x 9600). The baud rates selected for each terminal represent a compromise among what make sense for that terminal's capabilities, system performance requirements including human response times, and the overall system performance desired by Cali and the PRIME computer used to service his clients. Current performance speed as noted is satisfactory for the present level of production.

As noted in Figure 1, there is a portable TI 765 slow speed terminal with bubble memory that can be used to access any of the dial-up network services in current use. The GE Terminet 30 shown has been in use for several years. The Terminet, like the TI 765, operates at 300 baud. It contains a tape cassette memory as a local memory. To provide faster printout from the dial-up network services, one of the DECwriters has been equipped with a switch and a 1200 baud Vadic modem, thus providing an alternate use for that one DECwriter as well as increased line print capability for the dial-up services. All terminals except the GE Terminet were installed during June or July of this year.

It should be emphasized that the operation is completely terminal- and data-base oriented. In fact, the system is entirely free of punched cards and the resulting problem of a variety of program decks located in various desks through-out the office. Another feature is the absence of a high speed line-at-a-time printer. Our fastest printing device is the 2400 baud DECwriter III. As an example of the limitation, this unit takes about 40 minutes to print 132 pages of a ship's complete hydrostatic data. However, with three other printers and two viewing screens, this print speed limitation has not proven to be a problem.

The Calcomp plotter is a very high quality drafting machine capable of producing complete drawings either directly from the on-line data base or alternately from the pair of floppy disks. The plot data, in fact, can be transmitted from the PRIME 750 to the floppy disks and thence to the plotter in one step. The drawing size is limited to 33" x 60". Conventional drafting paper or mylar can be used with either pressurized ball point, liquid ball point or liquid ink (needed for plotting on mylar). Again the capability of the equipment satisfies existing needs and appears to be an effective, low cost, 1980 state-of-the-art operational facility.

In addition to these facilities at Moorestown, J. J. Henry also has computer terminals at most of its other locations. A network of IBM word processing computers, for example, is used to support that phase of the operations. An IBM System 3 for Management Systems, Accounting and Payroll functions is also in use. In addition, at least four programmable electronic calculators (two with attached printers) are in use at the Moorestown office with others in use at our other offices.

Training,

As you may well appreciate, a major aspect of getting a coordinated, expanded and improved computer capability into being has been the requirement for an increased level of computer-related training for a relatively large number of our employees. Unfortunately (or should I say fortunately), J. J. Henry has been extremely busy with project work and it has been difficult to schedule the number of individuals desired for the training programs that have been conducted. As a result, at this point in time we do not have the number of individuals fully trained, especially in the use of SPADES, that we would like. However, as a result of some excellent top level instruction given by key Cali personnel to a

relatively few J. J. Henry personnel, it is expected that we do have an adequate nucleus of trained personnel who will be able to share their knowledge with others as the production work load grows. Since last May, some 113 man-days have been invested in computer-oriented training, involving some 18 different J. J. Henry employees. All training has been conducted in Moorestown.

In order that the training be as useful as possible, it has been planned in a workshop format. As was mentioned earlier, our 19' x 24' computer room was designed as a combination computer operations and training area where the individual would receive not only classroom instruction, but also hands-on experience using terminals to access the individual host computer. For the GE Mark III and UCC Dynaflex training, additional portable acoustic coupled terminals were employed to make possible parallel use of the computer by those receiving instruction.

As was mentioned earlier in describing the computer room, sound absorbing tiles were installed on the walls. See Figure 2. This construction proved useful in training classes since training aids, drawings and computer plots and other computer printout could easily be mounted on the walls for general viewing. Along one end of the room, (at the head of the class) two 4' x 8' chalk boards were installed. One of these boards is embossed with the SPADES System Input Data Form for use by both the instructor and student. Shelves, supply cabinets, and work tables in the room provide easy access to required reference material, computer input forms, and other needed supplies. The terminals are installed along the outside walls since we do not have a raised computer floor. A plug-in phone, with a long extension cord, is available at the terminal for voice communication with off-site technical support personnel. This has been especially

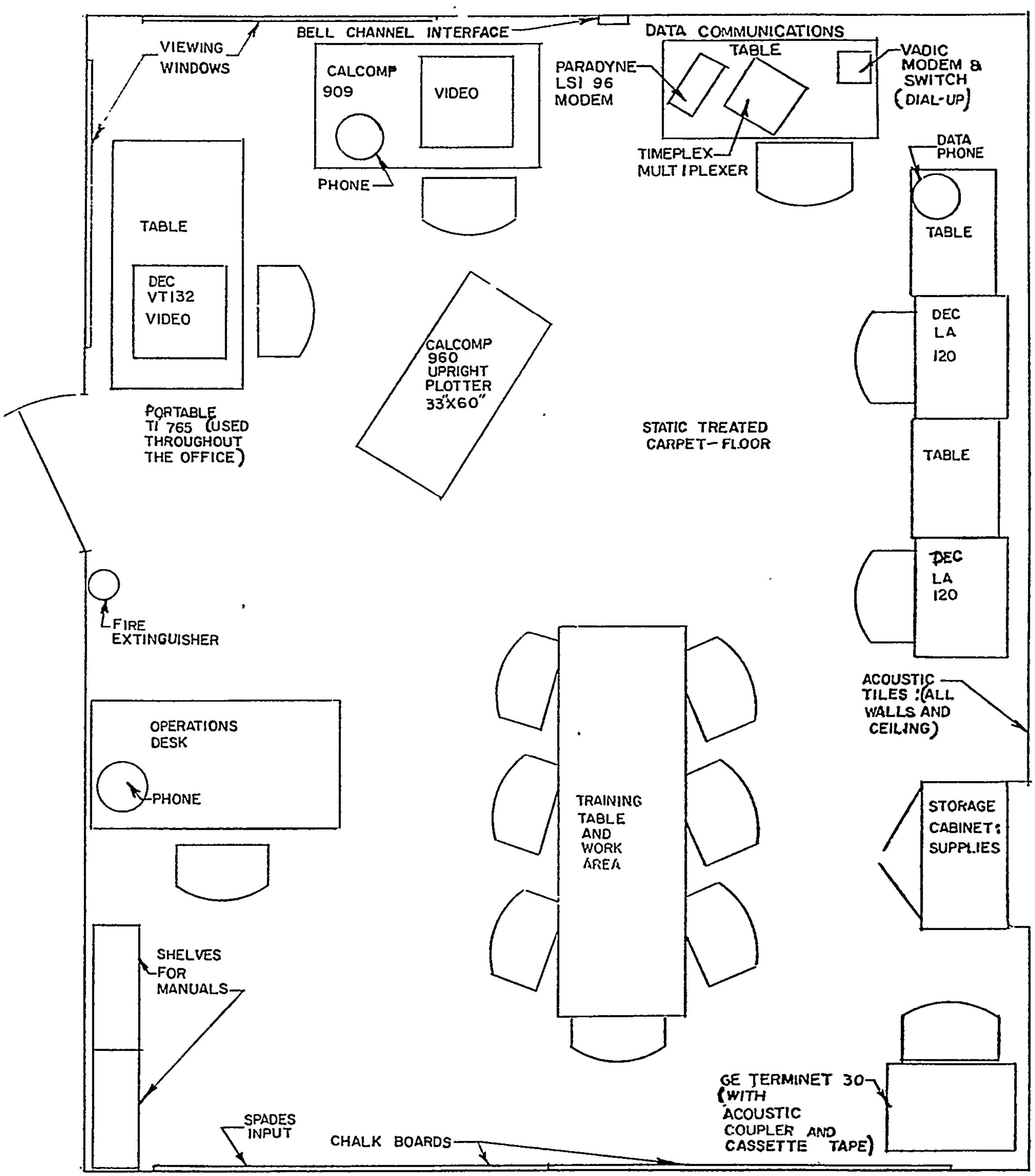


FIGURE 2, COMPUTER OPERATIONS CENTER AND COMPUTER - USER TRAINING ROOM - J.J. HENRY- MOORESTOWN, NJ.

helpful for the new user who is able while operating a terminal to communicate (using our WATS line) with service center support personnel whether the facility being used is in Metairie, LA, Rockville, MD, or elsewhere. In fact, such conversations with other Cali users, especially Stuart Whitman, formerly of NASSCO, were a big initial help to us in getting the Calcomp and DRAW portion of our SPADES service into effective operation. This audience doesn't need to be reminded that the Computer Network Service business is very competitive and a decision to select GE or Cybernet or whoever is often determined by the quality and helpfulness of the indivual technical support staff at the local office supporting the installation. This is especially true in an "open shop" environment where the individual engineer and technician directly use the network service.

Other facets of the training that should be mentioned are program documentation and operating procedures for using the various systems. Again the successful network service vendors do a good job in providing training programs and user documentation. With respect to SPADES, it has been necessary for J. J. Henry to create a good deal of the needed operational documentation and "how to" material. By applying a Highlighting Marker to such data as entered into the computer via the DECwriter, the resulting "record" has proven to be of value as a guide for training others. An advantage of the DECwriter use over the VT 132 is the availability of such audit trails. Organizing such "data" for effective future use is of value for training follow-up.

Training is an on-going process, a process that doesn't end with a successful start-up. A continuing investment of time and money is projected to continue in order to enhance our growing capabilities.

Problems

Any steps toward increased automation or computer-aided design will be unsuccessful unless there is initial and continued top management commitment and, may I add, "patience." The decision to carry out the computer usage expansion described was a top level decision by J. J. Henry Co. management, especially John Klose, Director, Hull Design; Dave McMullen, Assistant VP; Andy Brown, Senior VP, Moorestown Division; and Charlie Zeien, President. This decision was widely disseminated and understood throughout the Company. The commitment having been made, plans and schedules were developed and adequate funds allocated. The required equipment was placed on order and personnel from Cali & Associates made their time available to provide the necessary training. In general, the move to enhanced computer capabilities has gone quite well. However, a few problems have been encountered and our experience in resolving these problems may be of value to others.

With respect to the added terminal and communication equipment, the major problem has been in dealing with the multitude of vendors involved, i.e., Calcomp, DEC (Transnet), Paradyne and Timeplex (Noakes), TI (Westwood), Vadic (GE) and N. J. Bell. Each vendor met his delivery schedule with only minor slippages measured in days. By dealing with Noakes Data Communications for both the 9600 baud modem and the multiplexor, we were able to gain the experience of Cali's tie-in to five other off-site locations and install the particular communications equipment that was proving satisfactory in their current operation. With respect to this equipment, Noakes personnel were used for both installation and on-going maintenance, recognizing, however, that since the Noakes personnel are located in Irving, TX, trouble-shooting and on-site testing and repair must be carried out by J. J. Henry local staff taking advantage of advice and support from Noakes personnel via the WATS line.

As noted in the equipment section, only 4 of the 8 channels are in use and even those are not used to the maximum baud rates available, thus providing a service cushion. The maintenance of an effective data communication system is particularly sensitive to the multiple vendor problem, Since we have the most to lose, we have learned to recognize problem symptoms and take the responsibility in getting the problem resolved by dealing with Cali, N. J. Bell, and/or Noakes. Problems in this area which have occurred include the following: open circuit in Bell System at one of the junction points in our dedicated line, a defective board in our Timeplex multiplexor, and an incorrectly programmed microprocessor board in the multiplexor unit at Cali's office in Metairie. The data communications system itself has been designed to be nearly fail-safe with a variety of built-in automatic checks, and except for some very occasional data interrupts in the middle of on-line plots and some "lost data" on all terminals, the communications network has performed well to date.

The Calcomp 909 controller has had a fair amount of down time, totalling about 4 days over the period starting July 21. Service support is provided by the Calcomp personnel stationed in the Philadelphia metropolitan area and has been satisfactory. Usually the service response to a reported malfunction of the controller is within 24 hours, often within a few hours. The delay has not usually caused a serious problem since in the beginning the malfunction is usually intermittent rather than a hard "no-go.' The 960 plotter itself seems to be extremely rugged - in fact, except for some minor pen-skipping problems, there have been no difficulties with the plotter. The pen and vellum plots have been extremely good. Ink on mylar (required for some Navy contracts) is now satisfactory after some experimentation with different inks and pen sizes. The ink on mylar drawings are best when done from the "floppy' rather than on-line.

The procedure adopted is to make the drawing with pen on paper while copying the plot control instructions on to the floppy. After checking to see that the drawings are good, the floppies are scheduled for a succession of ink on mylar drawings in the local mode. The manuals provided by Calcomp are barely adequate and, in general, it has been necessary to adapt the material and re-document it for our operational environment. An operational procedure manual is maintained in the computer room and is updated as new, more effective ways of doing things are developed by our staff or others. We have been a SPADES user for only the past 3 months, but last March one of our staff attended their User Group Meeting. These meetings are held on an annual basis and provide an effective vehicle whereby the half dozen or so organizations using SPADES are able to effectively communicate with the individuals developing and maintaining the SPADES system. A major objective of these meetings seems to be the obtaining and prioritizing of user requests for system enhancements. From my long experience in the computer field, I know of no effective major service that does not have an active users' group. Such groups, in general, serve as an excellent means for training follow-up, getting user input for prospective system enhancements, and communicating planned changes.

In the training section, I indicated that it was difficult to free up personnal for required training. This was particularly difficult this past summer as a result of the heavy work load and the usual summer vacation schedule. Hopefully, our nucleus of trained personnel will continue to share this knowledge and experience with others who were not a part of the initial classes. The problem of converting the accumulated knowledge in using computer systems effectively into adequate, easily available, HOW TO documentation is a problem that will gradually be solved by continued attention. In using several other

computer network services besides the Cali SPADES system, J. J. Henry personnel are also confronted with the problem of doing things a little differently depending on which network they are using. Most such computer systems provide useful prompting; however, switching back and forth does require user adaptation and leads to some loss in efficiency. It should also be added that training without effective follow-up use is a wasted effort. On several occasions, individuals have been trained and then not had an opportunity to use what they have learned.

A final problem point is the heavy computer load frequently experienced in mid-morning and mid-afternoon on most computer networks. In particular, we are concerned over the success of Cali's computer network and the resulting heavy usage and the occasional resulting lack of capability of the network to provide an acceptable response time. The usual wait is often about an hour, but at times the wait for a production run can be much longer. Cali has recently simplified the procedure whereby his users can change the priority of the run they are submitting. Such changes require acceptance of a higher charge and since each user can see the listing of jobs in the queue, as well as each other's priority, there is danger that a priority escalation will increase Cali's income without actually improving individual service. In general, however, I must add that the PRIME 750 system has an excellent operating system with good response time, has a powerful editor and, in general, is a most acceptable price performance system in the 1980 marketplace.

Application

Before concluding, I believe it is desirable to at least list some of the broad range of application programs that we at J. J. Henry have found useful in effectively serving our clients. The major recent thrust, of course, has

been the various modules of the SPADES system, but from the following list it should be clear that SPADES is only one facet of our computer-aided design service. Included in the following list are some of the programs used by the NYC office primarily on the UCC Computer Network. The programs listed include a number of proprietary programs (including the SPADES modules, as well as a number of other programs that are only available on particular computer networks). Another group of programs were obtained from the U. S. Navy, i.e., the well-publicized CASDAC programs. Suffice it to say that we, as an organization, attempt to stay up to date with the continually more powerful and more effective computer programs available in our industry and to adapt those programs which are appropriate to satisfy most efficiently our client requirements.

Among these programs are the following:

1. GENERAL NAVAL ARCHITECTURAL
   SPADES: HULLCAL
   SHIP HULL CHARACTERISTICS PROGRAM (SHCP)
   HYDROSTATIC TABLE PREPARATION
   DAMAGED STABILITY REPORTS.

2. LINES GENERATION AND ALTERATION
   SPADES: FAIRING
   MODIFICATION OF "PARENT" HULL LINES
   GENERATING LINES BASED ON SERIES 60

3. SHIP HULL DESIGN AND DRAFTING
   SPADES: HULLOAD
   SPADES: DRAWING
   SPADES: DEMO
   SPADES: PART GEN

4. PIPE STRESS ANALYSIS
   DYNAFLEX
   TRIFLEX

5. SHIP MOTIONS
   SCORES
   SHIP MOTION AND SEA LOAD
   DYNAMIC TANK PRESSURE

6. SPEED/POWER ESTIMATION
   - SERIES 60 STANDARD SERIES
   - TAYLOR STANDARD SERIES
   - FULL-BODIED HULL FORMS

7. PROPELLER DESIGN
   - WAGENINGEN B-SCREW STANDARD SERIES
   - PROPELLER PARAMETER CALCULATIONS

8. STRUCTURAL ANALYSIS AND DESIGN
   - ANSYS
   - NASTRAN
   - BEAM/FRAME STATIC AND DYNAMIC ANALYSIS
   - MIDSHIP SECTION DESIGN AND COST ESTIMATION
   - HULL GIRDER DEFLECTIONS
   - HULL GIRDER SECTION PROPERTIES

9. SHIP ECONOMICS
   - LNG/LPG AND BULK CARRIER ECONOMICS
   - CONTAINERSHIP, RO/RO AND COMBINATION SHIP ECONOMICS

Conclusion

These remarks are an attempt to provide a status report on the use of computer-aided design at the J. J. Henry Co., Inc. as of October 1980. A solid foundation has been laid toward an effective computer-aided design service for our clients; however, a great deal more needs to be accomplished, especially insofar as integrating SPADES into our overall design services. For the future I expect to see a much increased volume of design and production services. On-line computer-based interactive graphics design is certainly a major next step as we continue to provide more cost effective design services for our industry in the years ahead.

Thank you.

USE OF AUTOKON DESIGN FACILITIES - A DESIGNER'S PRESENTATION OF AN ACTUAL CASE

Hans Oigarden
Chief Naval Architect
Shipping Research Services A/S
Oslo, Norway

Mr. Oigarden is currently responsible for the structural design section at Shipping Research Services.

He holds a degree in naval architecture from Newcastle University.

A U T O K O N   M O D U L E S

P R E L I K O N

Produkts scientific calculations related to ships. Included are hull definition, hull variation, hull drawing, hydrostatics, stability, launching, capacities, ullage and sounding, grain stability, speed/power etc.

F I L I P

Two-way connection between PRELIKON and AUTOKON. Generation of preliminary lines to AUTOKON.

B O F

BOF is a programme for fairing of surfaces, and generates linplan and body plan complete with drawings and lists.

L A N S K I

Used for completion of body plan fitting landings of internal shell structures on shell surfaces. Handles also cutout information in longitudinal stiffening.

T R A L O S

Defines longitudinal surfaces internally in the hull, like decks with camber and sheer, bulkheads and stringers, and provides offsettables for surfaces.

T R A D E T

TRADET defines all stiffening on surfaces defind by TRALOS, in addition, seams and butts of plats in the surfaces are defind together with cutouts for penetrating profiles. Defines transverse frames on the shell.

D R A W

Programme for generation of graphical information based on data stored from TRALOS and TRADET. Drawings are detailed for the design and drawing office giving substantial improvement in total drawing efficiency.

TRALOS / TRADET / DRAW

Features:

- Definition of the main surfaces in the ship
- Definition of cut-outs
- Definition of profiles and stiffenings
- Definition of plate seams and thicknesses
- Simple input to the program
- Complete list of profiles used on the surfaces
- Easy updating of data due to topological description
- Generation of detailed drawings of the surfaces, including profiles and seams

For classification, steel and work drawings the modules TRALOS, TRADET and DRAW are used. These modules are used together with the other AUTOKON modules and store the results in the AUTOKON database. The results are stored both geometrically and topologically which means that the data are related to each other. By changing some data you will automatically have all related data updated as well.

This special feature makes it possible to drastically reduce the hours needed for alteration of drawings. At the same time you will always have access to the latest edition of drawings, and these drawings will show the correct geometrical results.

The TRALOS module is used for definition of any internal longitudinal surface in the ship. The surfaces can be plane (parallell to the center line or curved with chamber and sheer or twisted. Or the surface can be a combination of the mentioned. TRALOS will handle any type of conventional longitudinal surface unless it has to be faired. It can also handle inner surfaces connected to an unsymmetrical body plan. The programme can handle three main groups of surfaces depending on the transverse configuration of the surface. Horisontal surface (HSUR) defining decks, tanktop etc. which do not have any vertical lines. It will be used for symmetrical body plan. The same type of surfaces, but for unsymmetrical bodyplan (WSUR), and finally vertical surfaces such as girders or similar which do not have any horizontal lines.
Long L bulkheads (VSUR).

TRADET

The module TRADET store all the detailed data related to a TRALOS generated surface in the AUTOKON DATABASE, such as:

- 0 Profiles, beams and girders
- 0 Definition of all seams and butts describing type of joint, extention and related plate thicknesses
- 0 Definition of minor internal structures, including extension and connecting surfaces
- 0 Definition of connections between surfaces with necessary identifiction and type of connection, such as open, water tightness etc.

The profiles are split into relevant groups and will be identified with a profilenumber and the side of the sip where they belong. Profile orientation is established according to the "view" from which the profile is seen.

Joints between the various parts are called seams. The seams are also split into relevant groups and are identified as for the profiles. Additionally the thickness and type of weld is taken into consideration.

DRAW

The DRAW module is used to generate drawings with different levels of detailing.

Scantling drawings which includes graphical lines of any structure penetrating the drawn surface.

If the penetrating profiles have been defined the drawing will also include the cutout contours.

Structural drawings which include information of the scantling drawings plus the graphical details belonging to thew surface itself such as:

- 0 Stiffeners
- 0 Seams
- 0 Connections of minor and major parts
- 0 Inner contours

"Windows" can be defined for detailing of the drawing. Symbols are added for the seams. Stiffeners and profiles, minor or major structures, will be drawn either with a continuous line or various dotted lines depending on the type of connection and profile loction. (This side or other side).

RESTART PROG : R
TEGN UTEN REPOS : S
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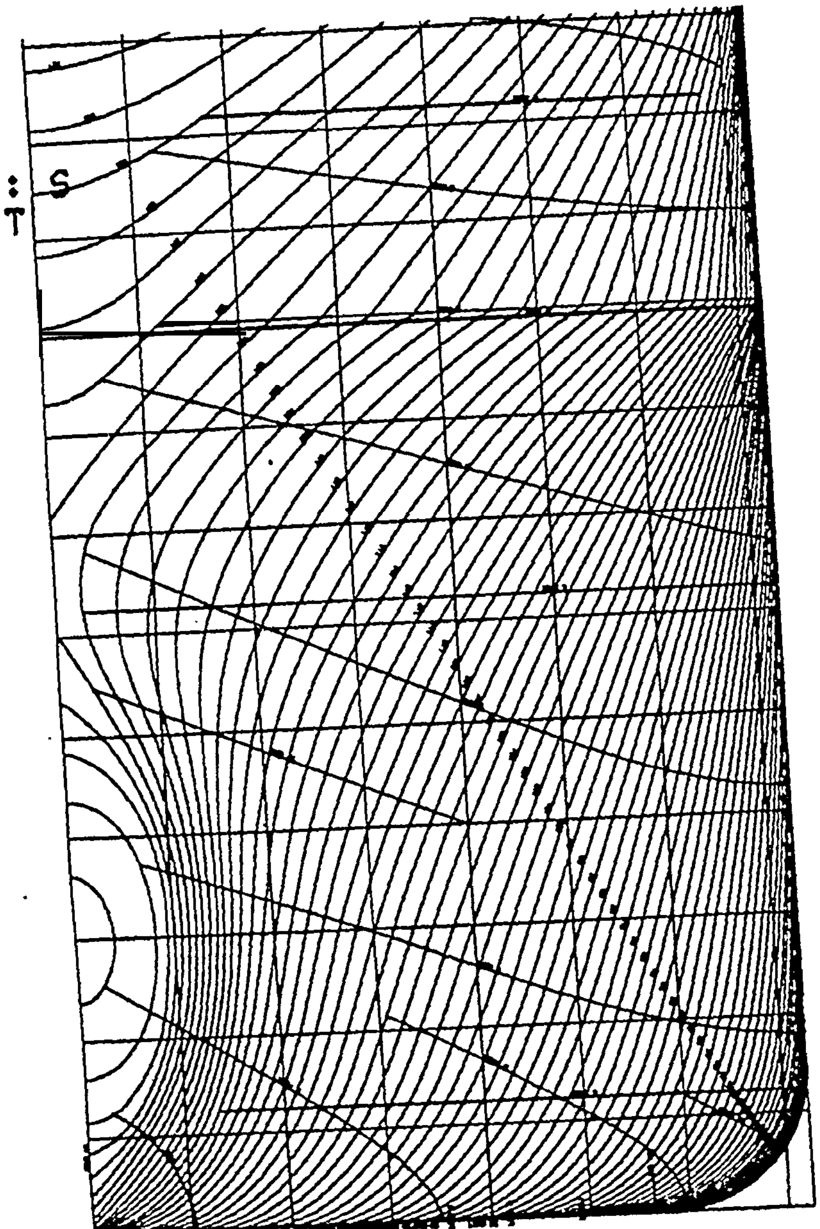

BRATTVAAG SKIPSINNREDNING B/N 37
FORSKIP
SPANTERISS

RESTART PROG : R
TEGN UTEN REPOS : S
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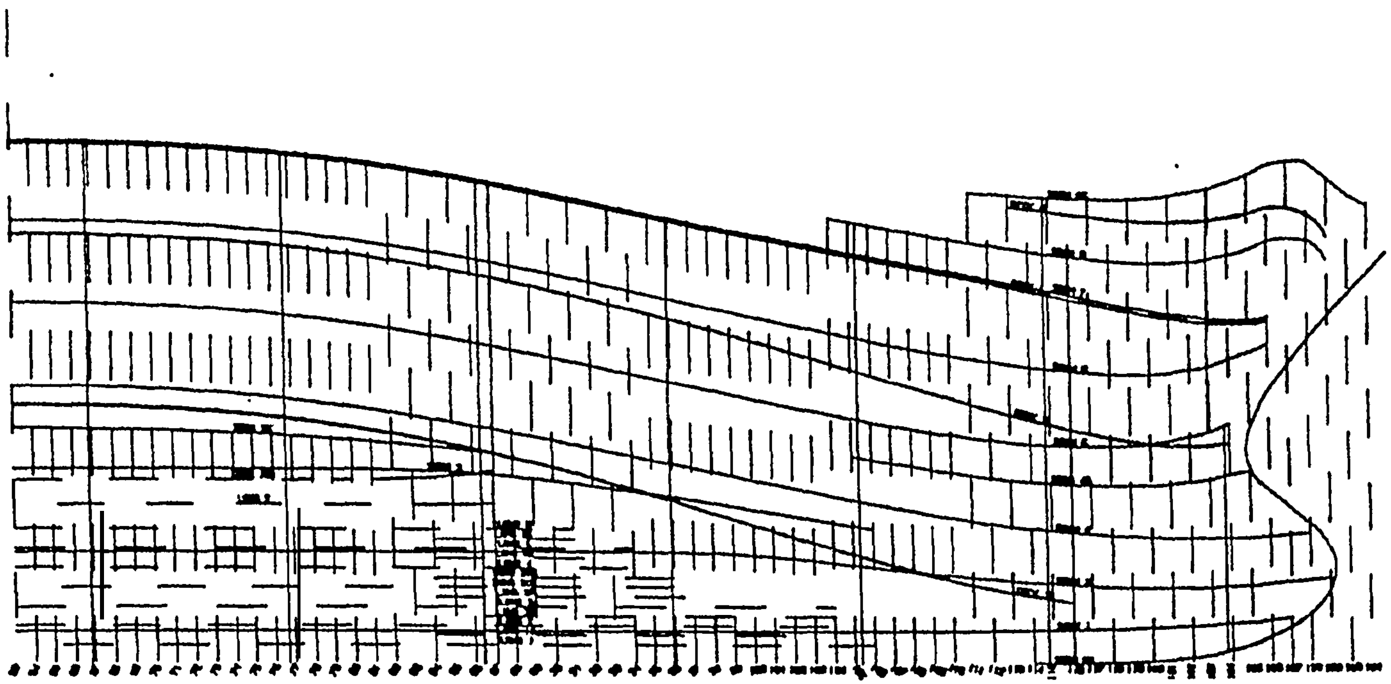

BRATTVAAG SKIPSINNR. B/N 37
FORSKIP
HUDUTFOLDING/SHELLEXPANSION

```
D DO? YOU? WANT TO CONTINUE  (OR SKIP) (Y/N/SK) ... : Y
 [illegible] (Y/N) WILL ALSO CLEAR SCREEN
 'D' CONTINUE FROM LAST POINT
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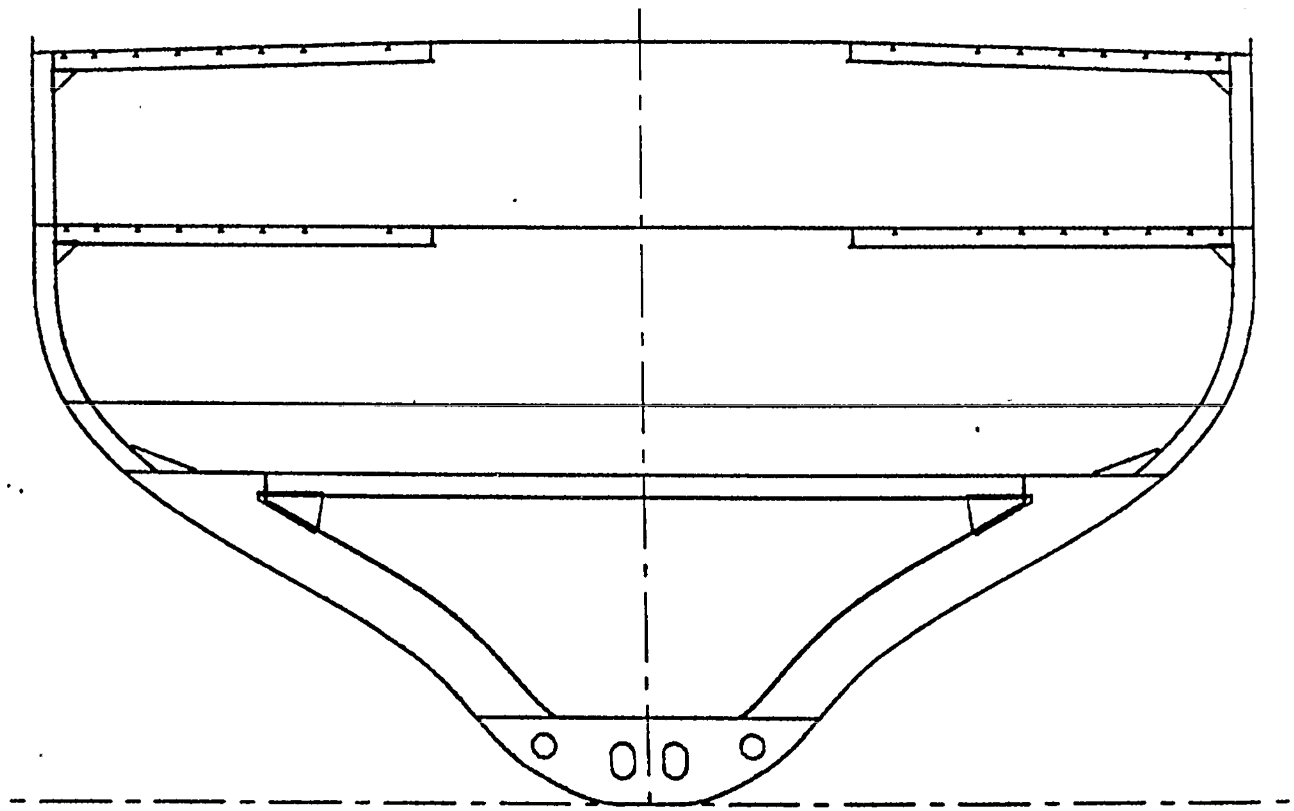
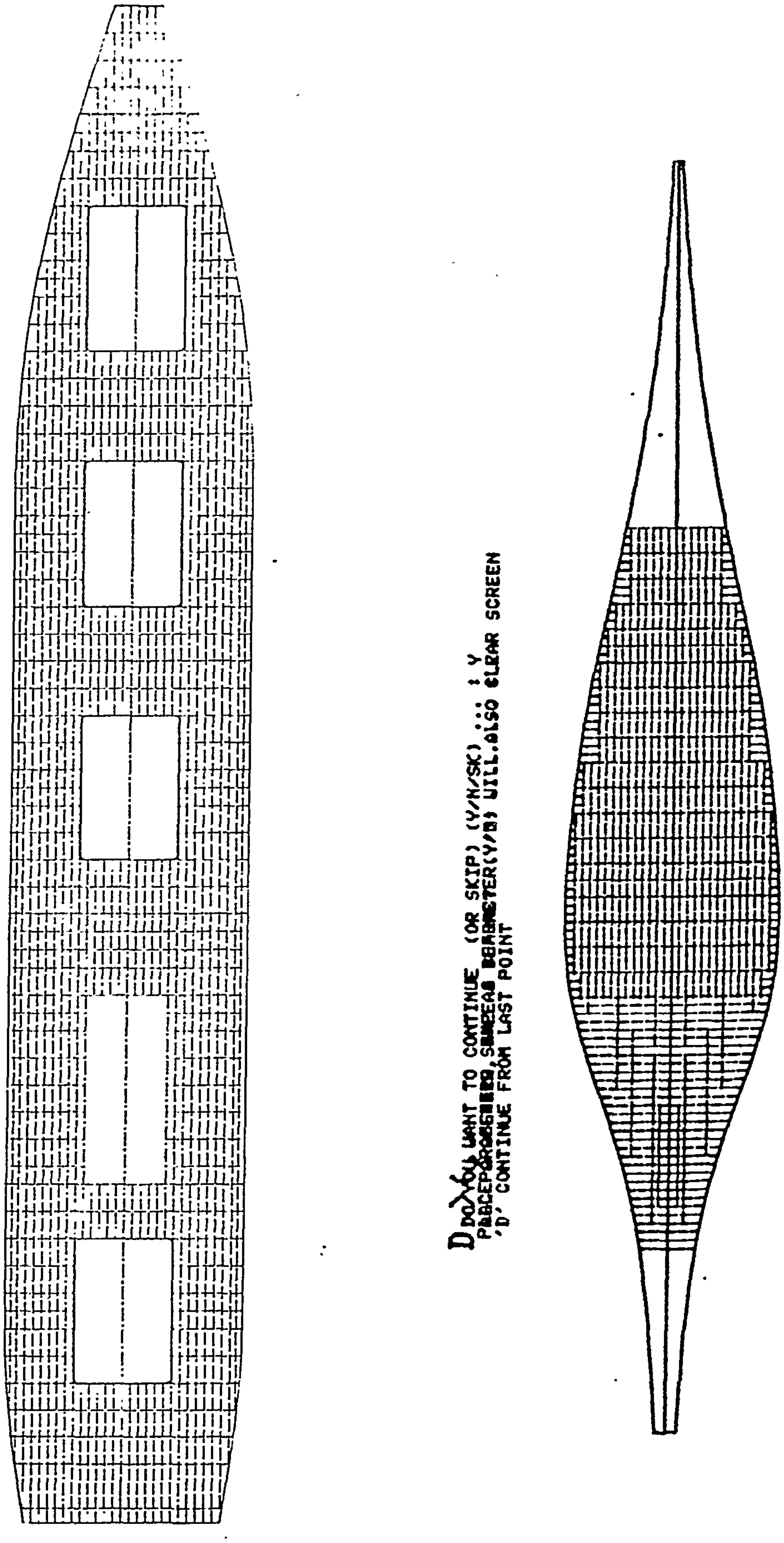



DO YOU WANT TO CONTINUE (OR SKIP) (Y/N/SK) ... : Y
'D' CONTINUE FROM LAST POINT

CASE STUDIES.

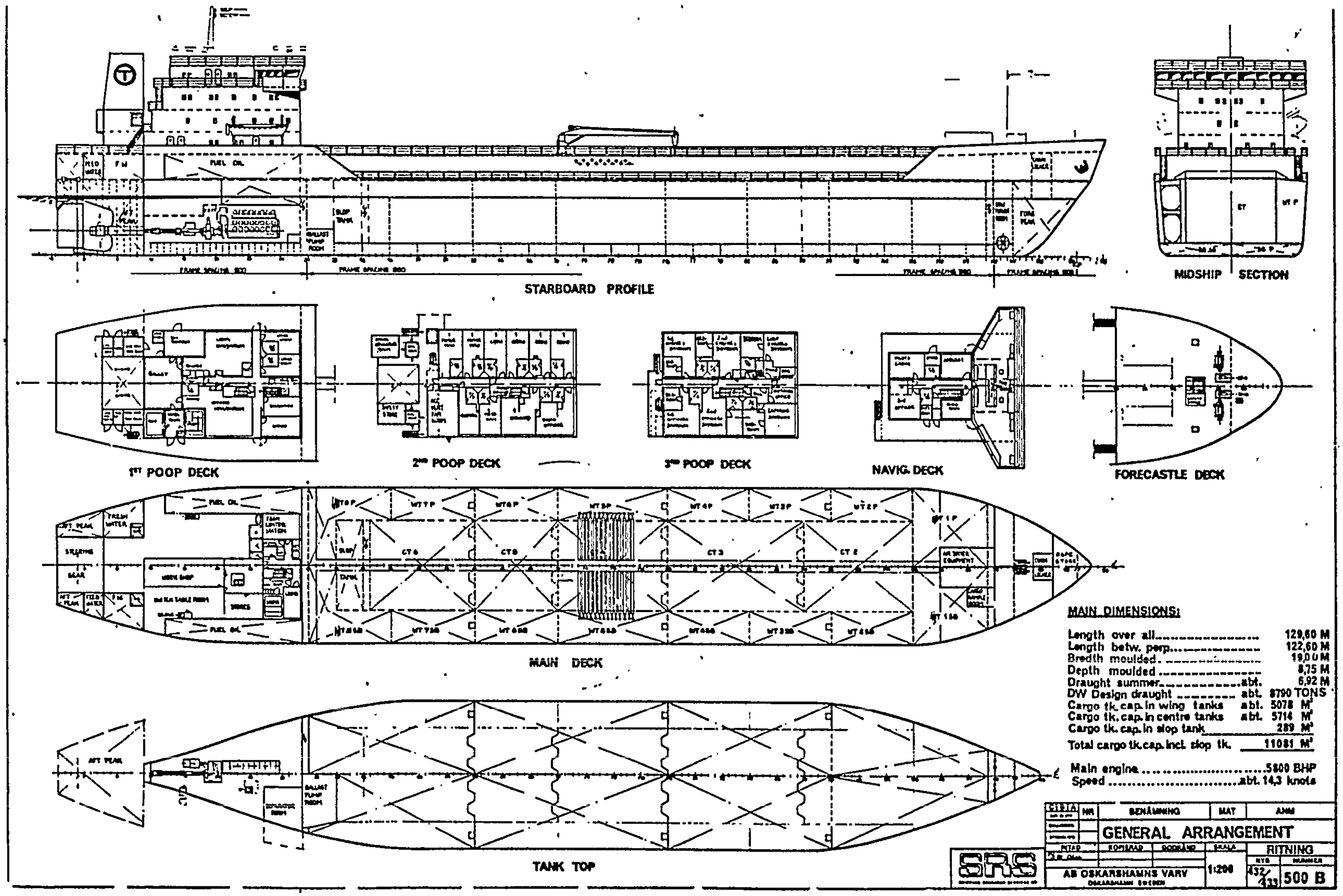
CHEMICAL CARRIER.

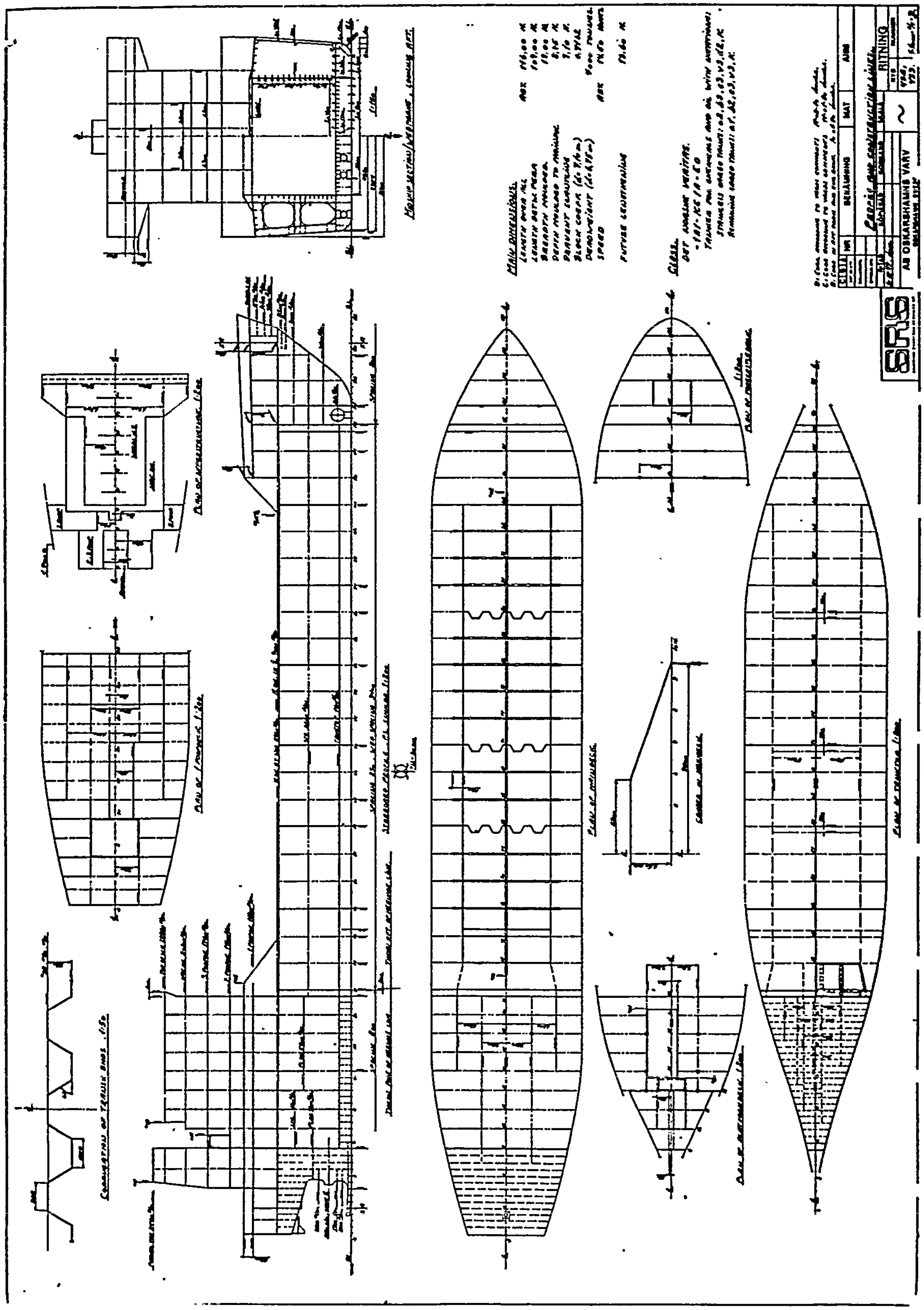
Main dimentions:

Length over all_______________________ 129.6 M
Length betw.perp.____________________ 122.6 M
Bredth moulded 19.0 M l
Depth moulded________________________ 8.75M
Draft summer ____________________ abt 6.9M'
DW Design draft______________ abt 8790 TONNES
Speed______________________ abt I4.3 KNOT
--------------------------mm------

SRS scope of work for this. project:
Project drawings and documentation.
Classification drawings, steel, machinery,
Accommodation, outfitting.
Working drawings, steel and steel outfitting.
Pipe diagram, pipe arrangement and pipe scetches.
Complete lofting.

Work done for this project utilizing TRALOS and TRADET were taken to classification level and windows were taken to create workingdrawings.

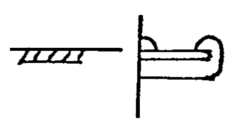

STARBOARD PROFILE
MIDSHIP SECTION
FUEL OIL
1ST POOP DECK
2ND POOP DECK
3RD POOP DECK
NAVIG. DECK
FORECASTLE DECK
MAIN DECK
TANK TOP
MAIN DIMENSIONS:
Length over all .... 129,60 M
Length betw. perp. .... 122,60 M
Bredth moulded .... 19,00 M
Depth moulded .... 8,75 M
Draught summer .... abt. 6,92 M
DW Design draught .... abt. 8790 TONS
Cargo tk. cap. in wing tanks abt. 5078 M³
Cargo tk. cap. in centre tanks abt. 5714 M³
Cargo tk. cap. in slop tank 289 M³
Total cargo tk. cap. incl. slop tk. 11081 M³
Main engine .... 5800 BHP
Speed .... abt. 14,3 knots
NR
BENÄMNING
MAT
ANM
GENERAL ARRANGEMENT
RITNING
AB OSKARSHAMNS VARV
1:200
432/433
500 B

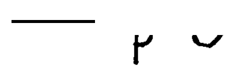

AB OSKARSHAMNS VARV
RITNING

when this project was started utilizing ITC software, the classification drawings were finished and done in the traditional way. This ment that all the classification drawings had to be defined in TRALOS and TRADET. This work were done mainly by two men. One from the lofting department and one from the structural design department.
These two men did not have any experience with TRALOS or TRADET.
They started the work after a crush course lasting for **1.5** day, and then they were working together for about two weeks. Then the steel man was supposed to do the remaining input to TRADET, and to take out windows from the main drawings, and to assemble these to create working drawings.

During this week, it of course were detected bugs and faults in the program package. But also one of the reasons for this project were to detect faults, and then to correct the programs.
So for this project a lot of time were spent just in finding ways to get around problems, and to adjust the program.

Some of the problems we run into during the work were for instance to get the cutouts for flatbars on the correct side of the flatbar.

What we wanted 

And what we got 

This cutout is usually controlled by the direction of the flange of a profile.

Another funny thing we found when the lofting people started their work, the cutouts disappeared for the profiles in double bottom when they picked up the contours for the floors in double bottom.

The sequence in numbering profiles is important.
Always from centreline to shell, and from deck to bottom.
In theory it should be general, but some times the numbering was done from bottom to deck, and that ended usually up in defaults.

The type of lines which are possible to choose in the program is somewhat restricted.

Different types available:

----------------	stifft
______ . ____ .	girder, beams
______ . - l	non water tight bulkhead
- - -	water tight bulkhead

The control of which type of line is wanted is done by type of connections given for the different surfaces.

And for stiffeners, -ve or +ve type number of stiffener are given, -ve gives - . - . - line.

Equipment

This project was run batch against Univac **1100.** Taking out papertapes, and making the drawings with a calccumpplotter. This was only to verify the content on the papertape, then the same tape was used on a Kongsberg drawing machine, and the drawing was made in ink. When using this equipment, a lot of time was wasted when waiting. First waiting for the Univac **1100** to be ready; then the checking of papertape:and final a rather slow Kongsberg drawingmachine which we have. So for this project, the tool used was definetly not the best to be used.

Economv of this Project

This item might be the most interesting part.

Total worked hours with TRALOS, TRADET and DRAW:	680 hours
of these hours about 300 hrs direct waste getting the system working. About **100** hrs. waiting for the Kongsberg drawing machine.	
The working drawings was calculated to be	4500 hours
Total hours spent for working drawings including TRALOS, TRADET and DRAW	-3750 hours
Saved time	750 hours

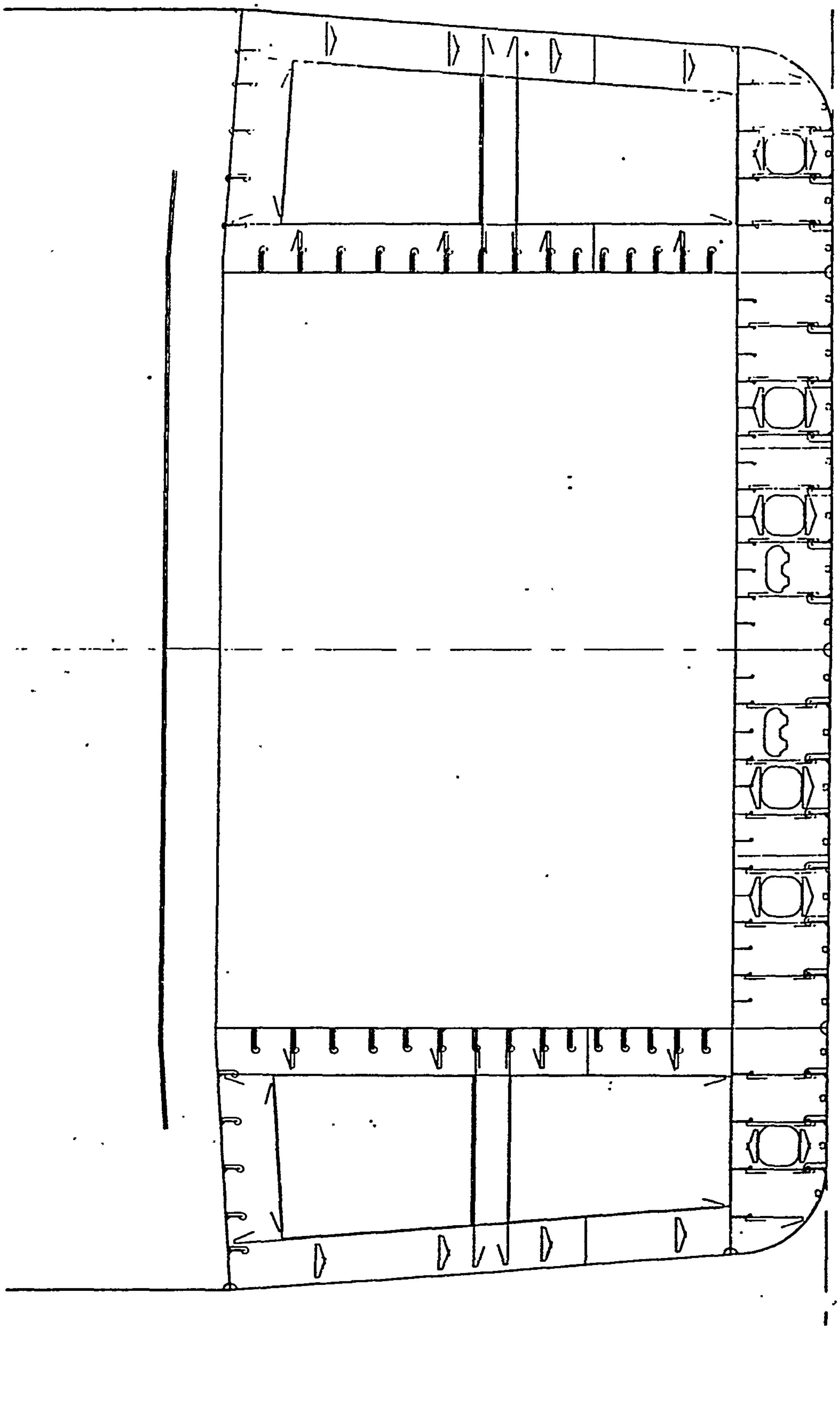
Reduction 16,6%.

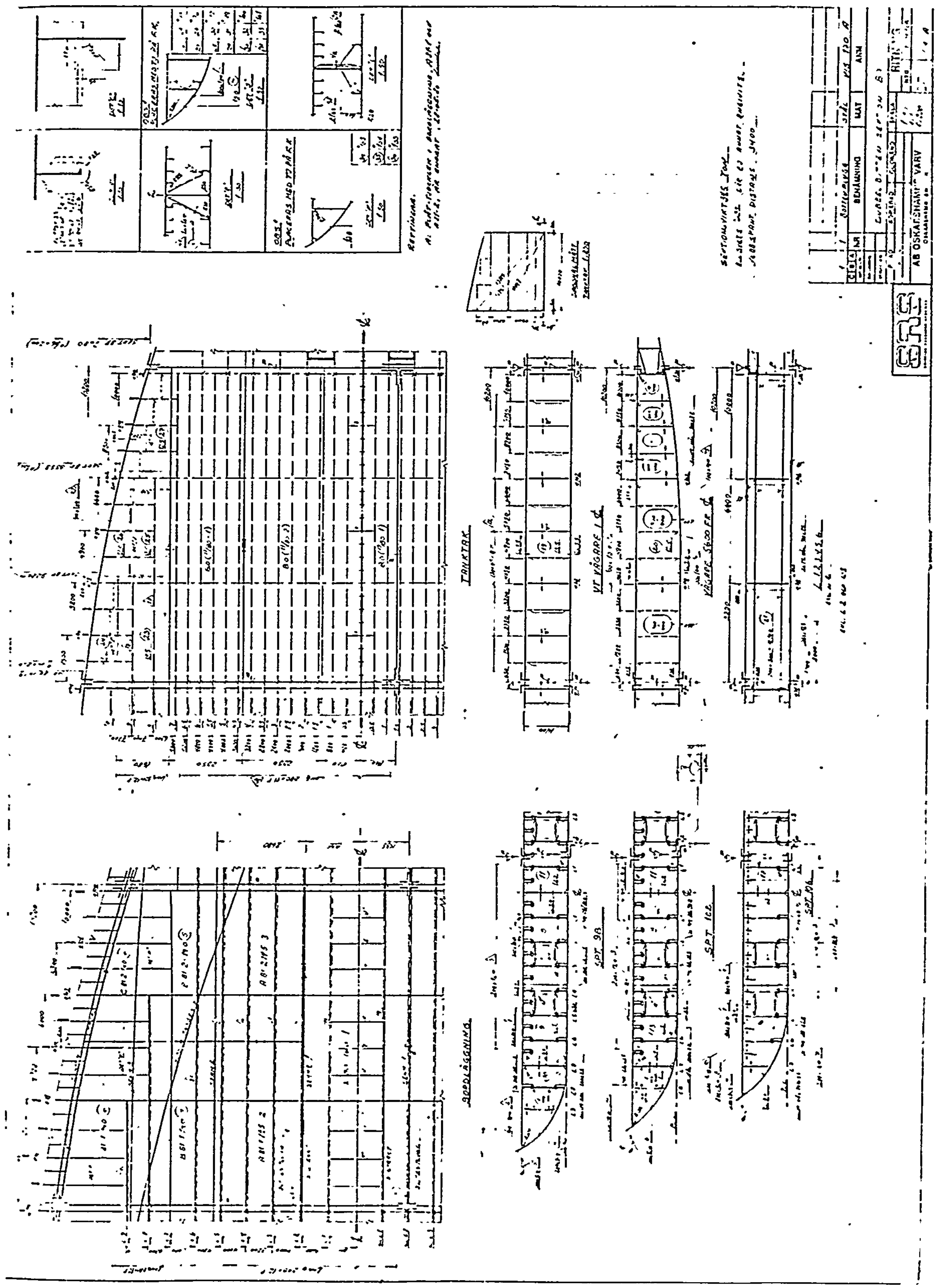
If the project was run smoothly and with better tools, about 400 hours could have been saved i.e.

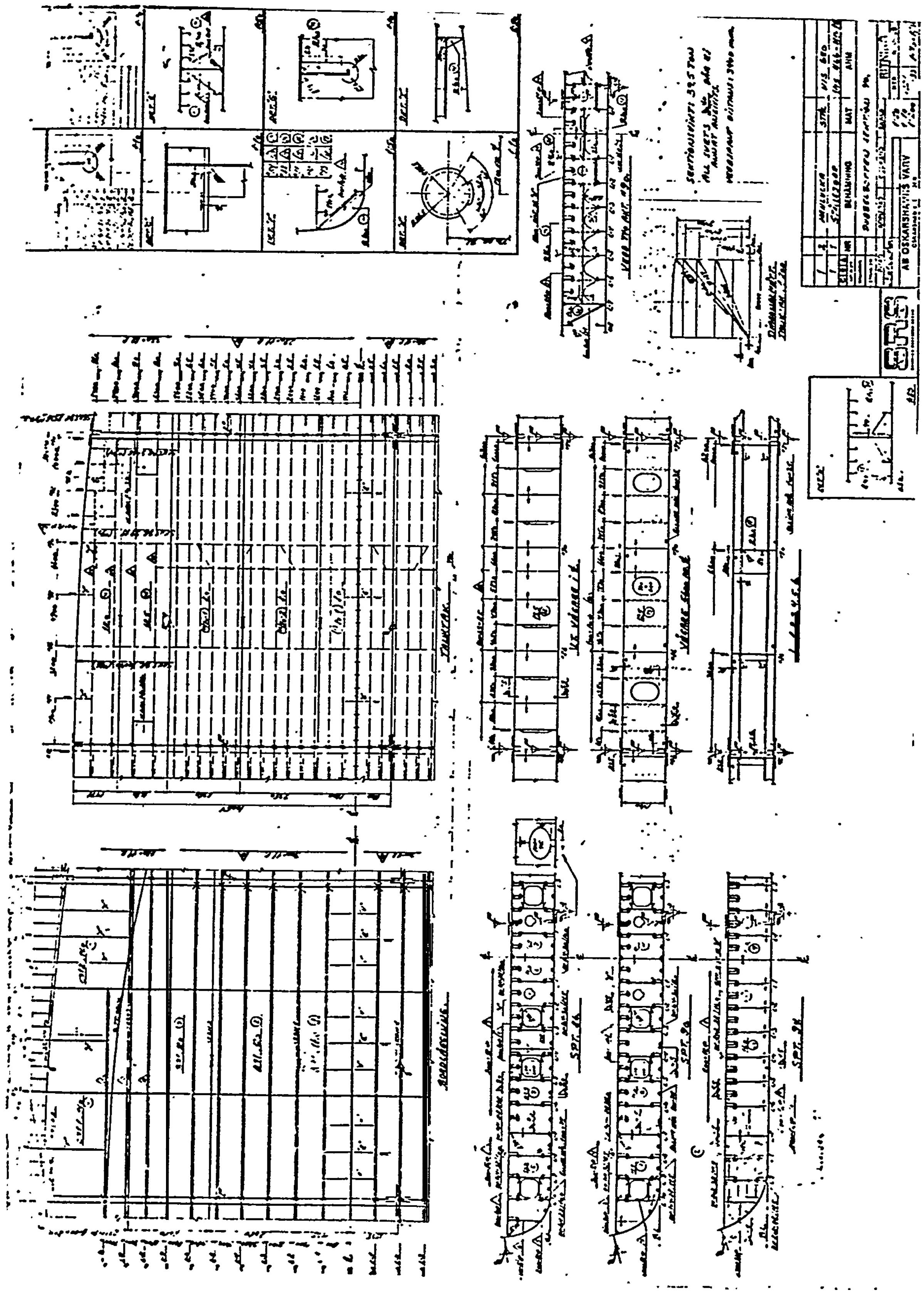
	4500 hours
-	**3350** hours
	1150 hours

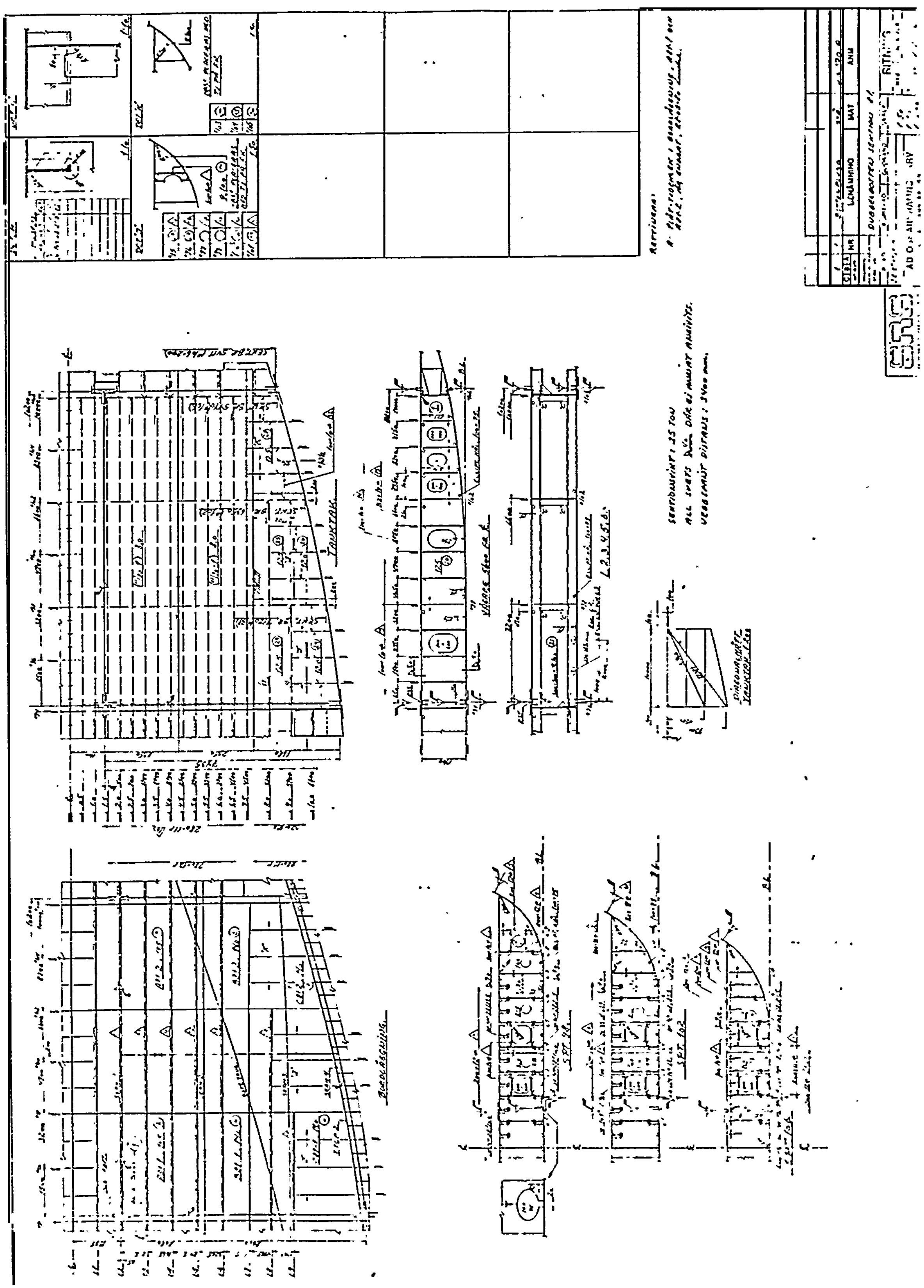
Reduction 25.5% possible.

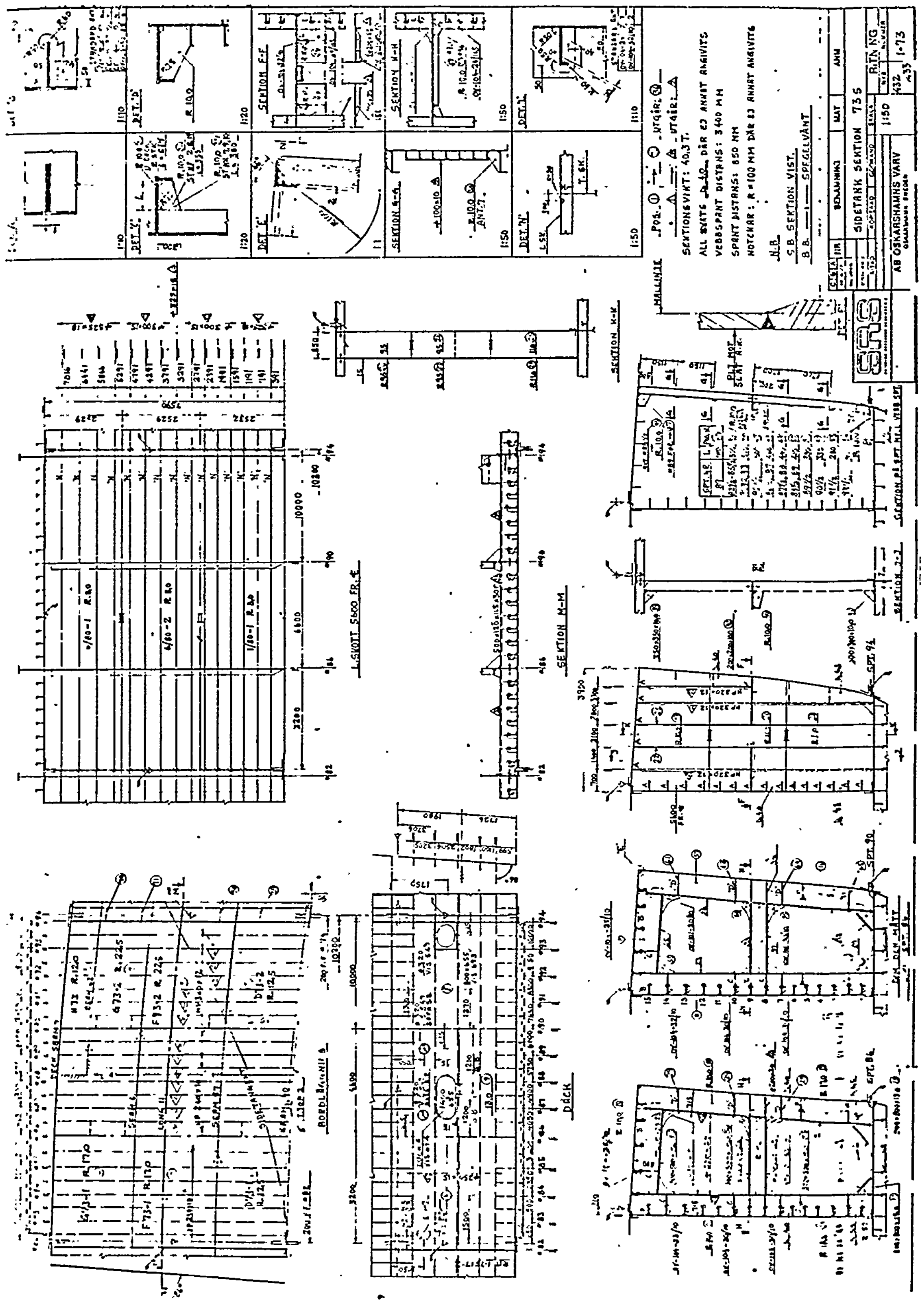
But to keep in mind, we have only been dealing with working drawings.
Classification drawings could have been done with TRALOS and TRADET for this project, and even more manhours could have been saved.

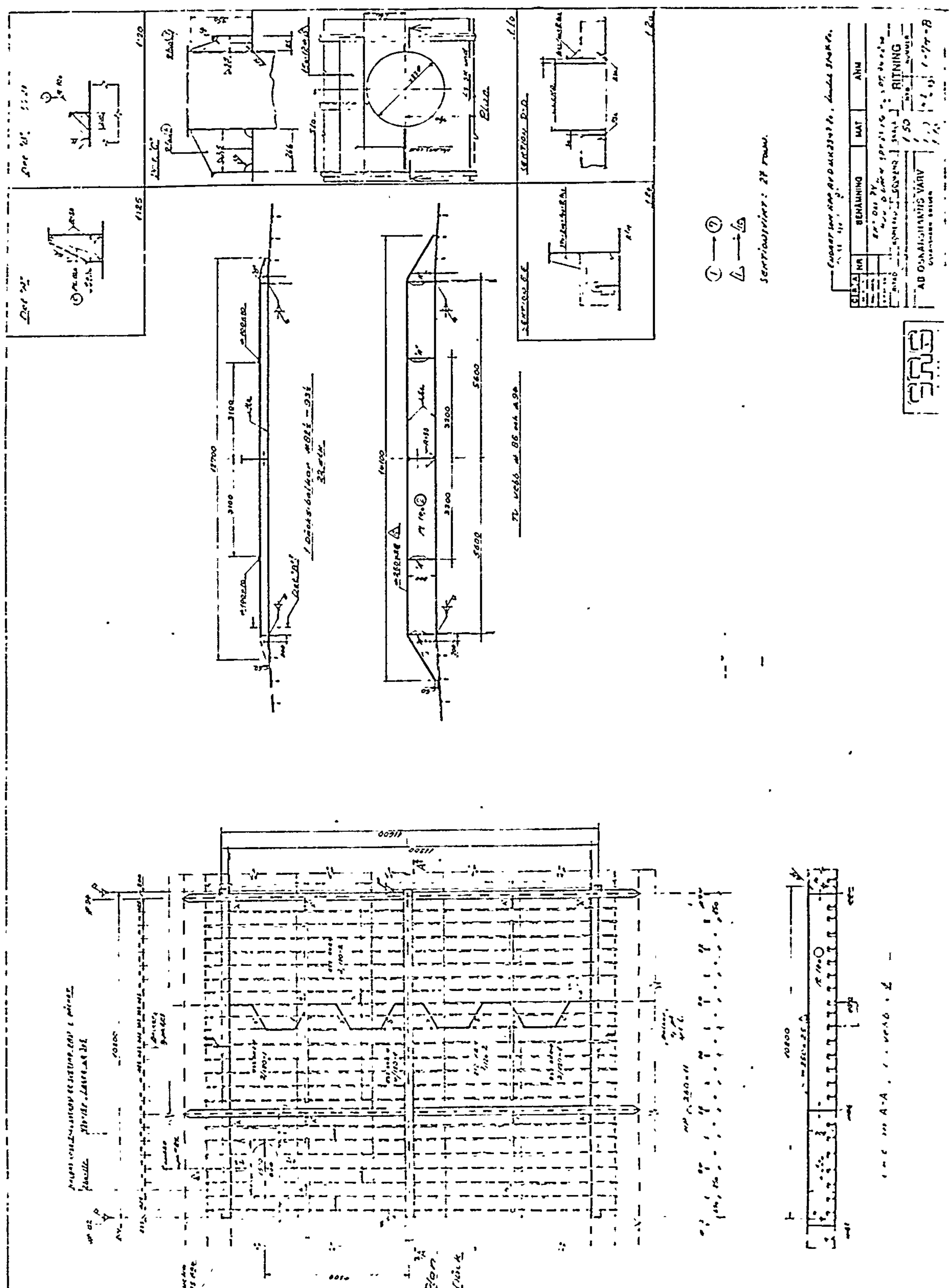


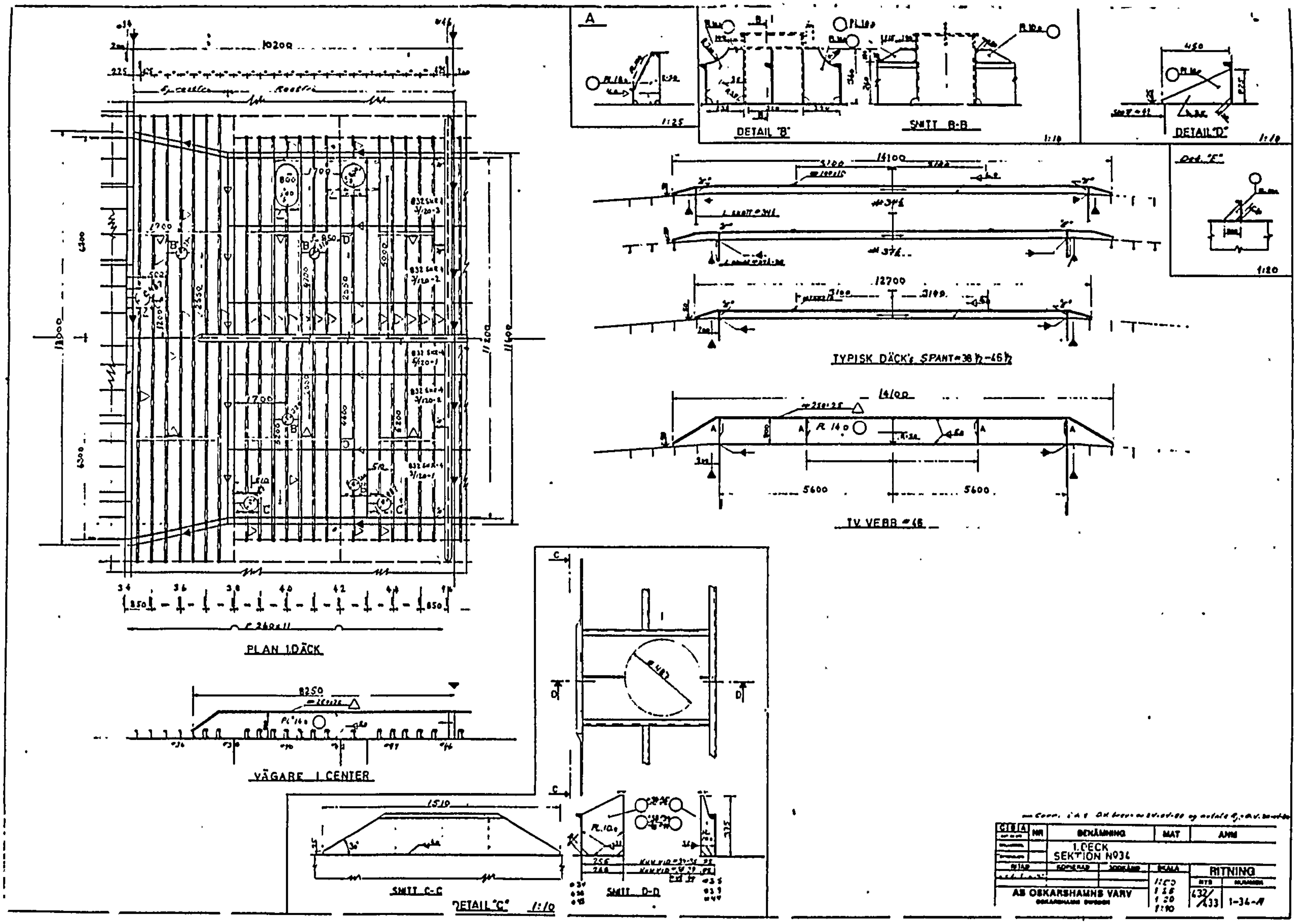







SIDETANK SEKTION 735
AB OSKARSHAMNS VARV
RITNING
SEKTION M-M
SEKTION K-K
DÄCK
BORDLÄGGNING




A
1:25
DETAIL "B"
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14100
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TV VEBB #46
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11600
PLAN 1.DÄCK
8250
VÄGARE I CENTER
1510
SNITT C-C
DETAIL "C" 1:10
SNITT D-D
BENÄMNING
MAT
ANM
1.DECK
SEKTION N034
RITNING
AB OSKARSHAMNS VARV
1-34-4

CASE STUDIES.

PASSENGER CARGO VESSEL
Main dimentions:

Length over all---__-__------------ 101.8 M
Length betw.perp.,------------------- 92.4 M
Bredth moulded---------------------- 18.0 M
Depth mouided-------m-_--e---------- 12.OM
Depth moulded to bhd deck____-------- 6.8M
Max draft--------------------------- 5.0M

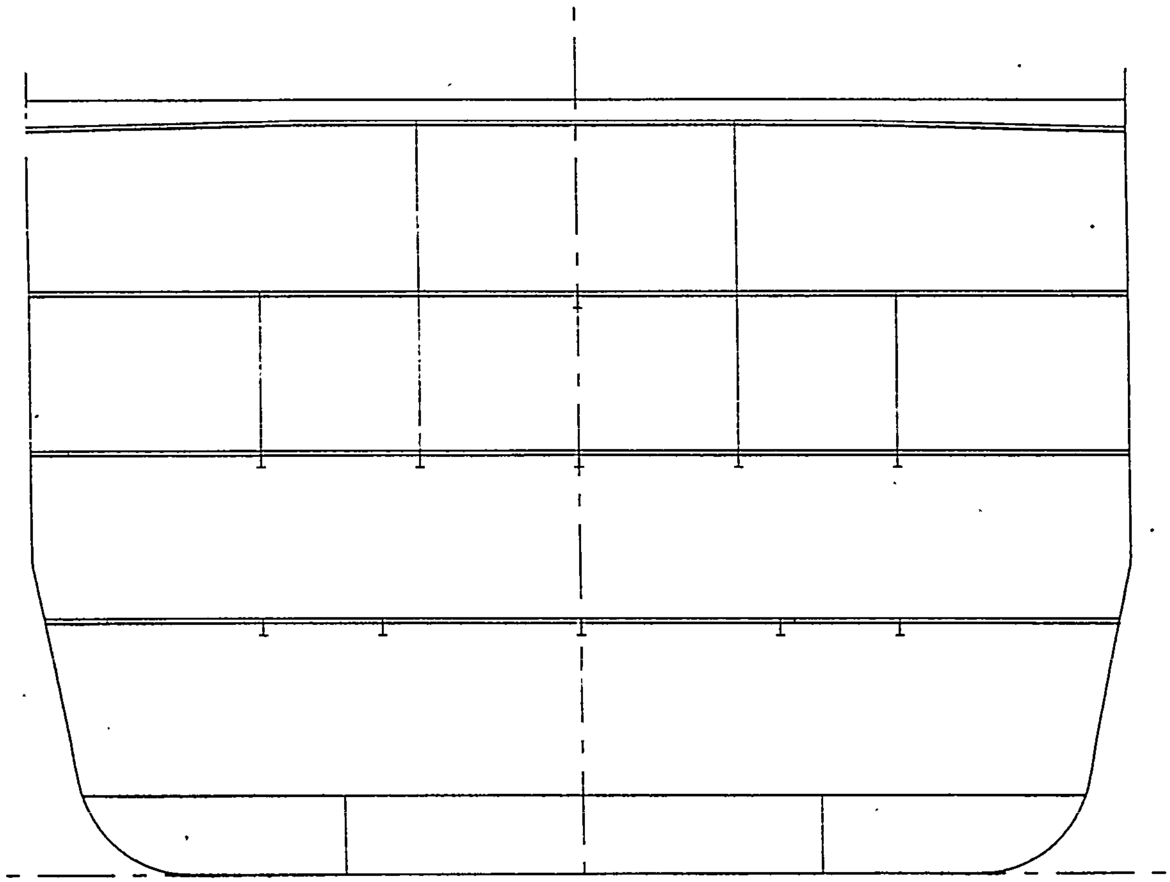
SRS scope of work for this project:
Project drawings and documentation.
Classification drawings, steel, machinery,
Accommodation, outfitting.

Work done for this project utilizing TRALOS and TRADET were taken to classification level.

Two main purposes for this project were to test out the new version of TRALOS and TRADET, where it is possible to give the input in feet and inches, and to do the classifiction drawings based on preliminary lines done in Prelikon and connected to Filip to establish framenumbers which TRALOS and TRADET are dependent on. Then after fairing of lines, the preliminary lines were interchanged with the final lines.

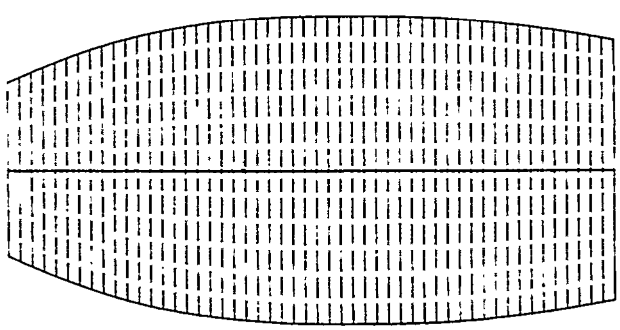
For this project people from two other norwegian yards were joining a course together with the structural design staff. This lasted for one week, and during this week all the attendent managed to do the input for this vessel.
The actual time spent on TRALOS and TRADET were 1.5 day.

The input was done on alpha nummerical screens as a terminal to our Prime 750 Computer. Drawings taken out on a tektronix graphic screen for checking. Then finally drawn in the wanted scale on the calcompplotter.
For this project a Hewlett Packard 45B was tested out, to see how this worked as a terminal to the Prime, and also to see if the graphic screen on this desktop computer worked satisfactory.
The result was satisfactory, but some minor adjustments have to be made so the system becomes more streamlined.



70

PRELIMINARY LINES



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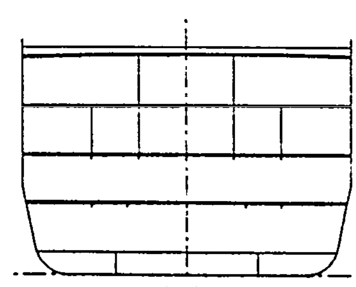

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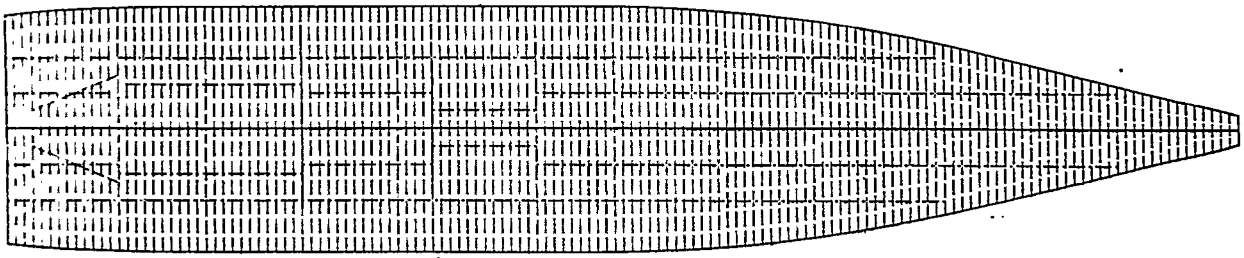
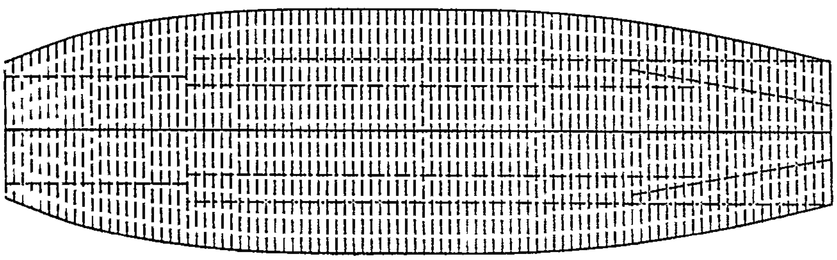
PRELIMINARY LINES

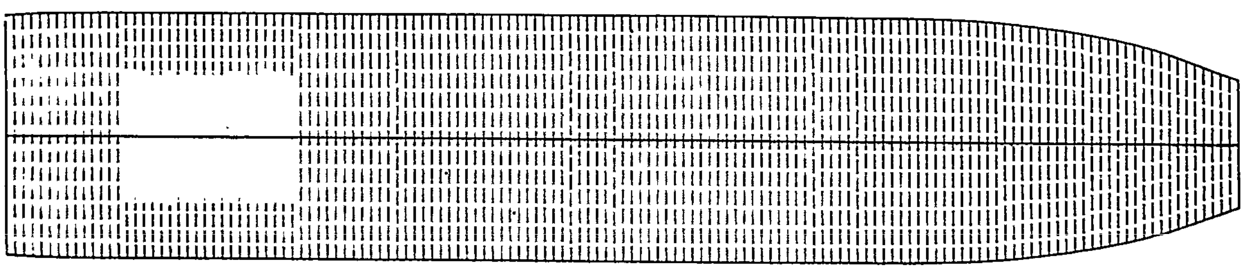


4. DECK



3. DECK

PRELIMINARY LINES



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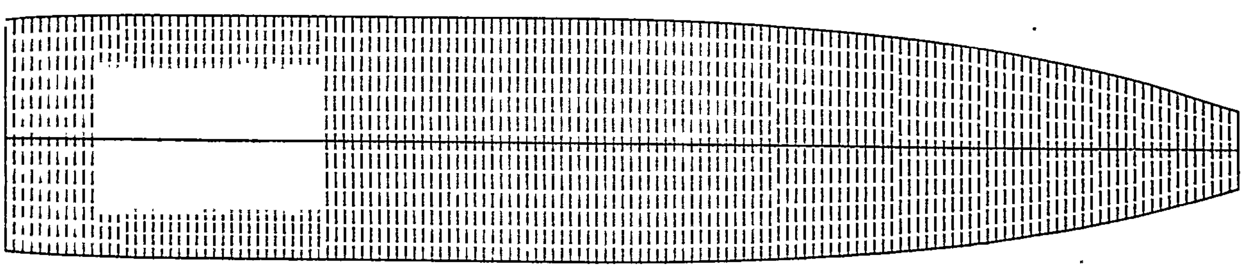

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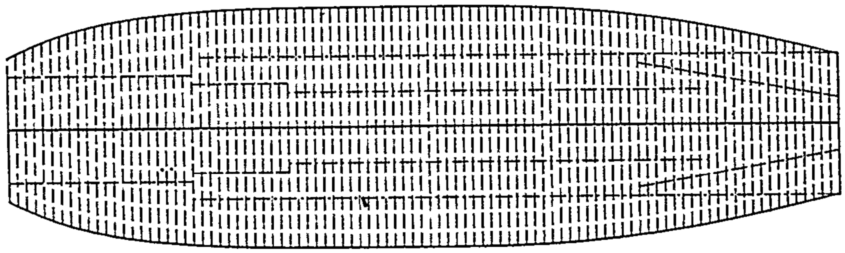
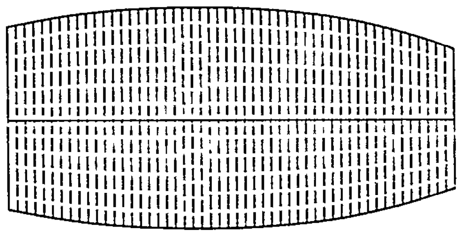
PRELIMINARY LINES



1. DECK



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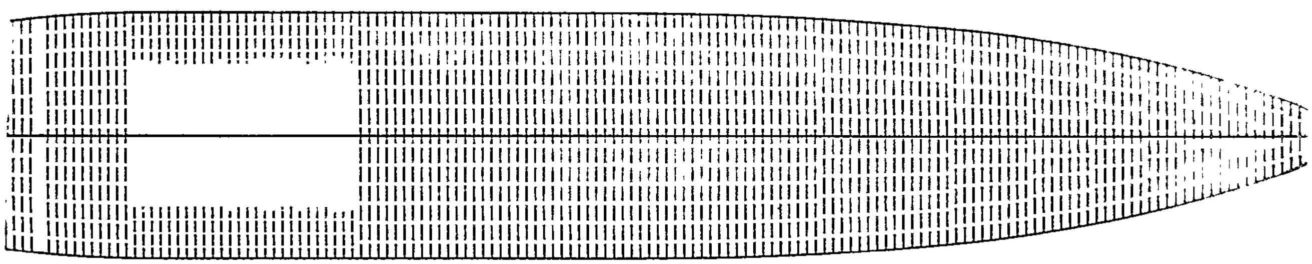
FINAL LINES



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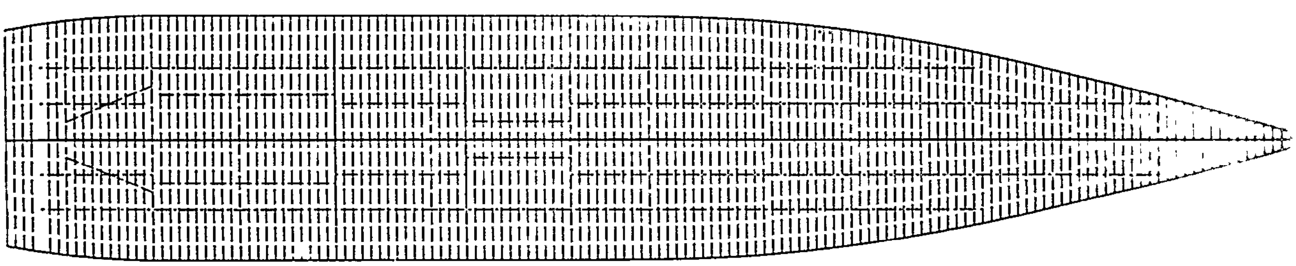
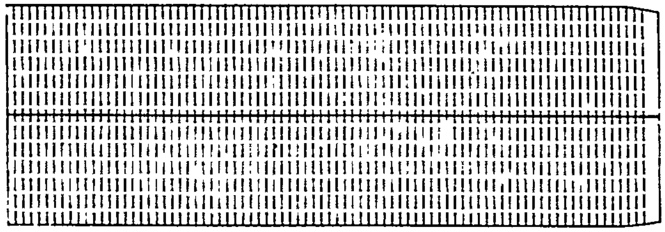
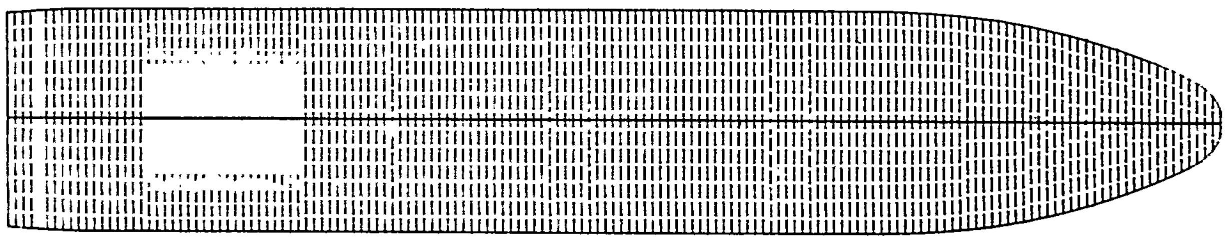


2. DECK

FINAL LINES



5. DECK



4. DECK

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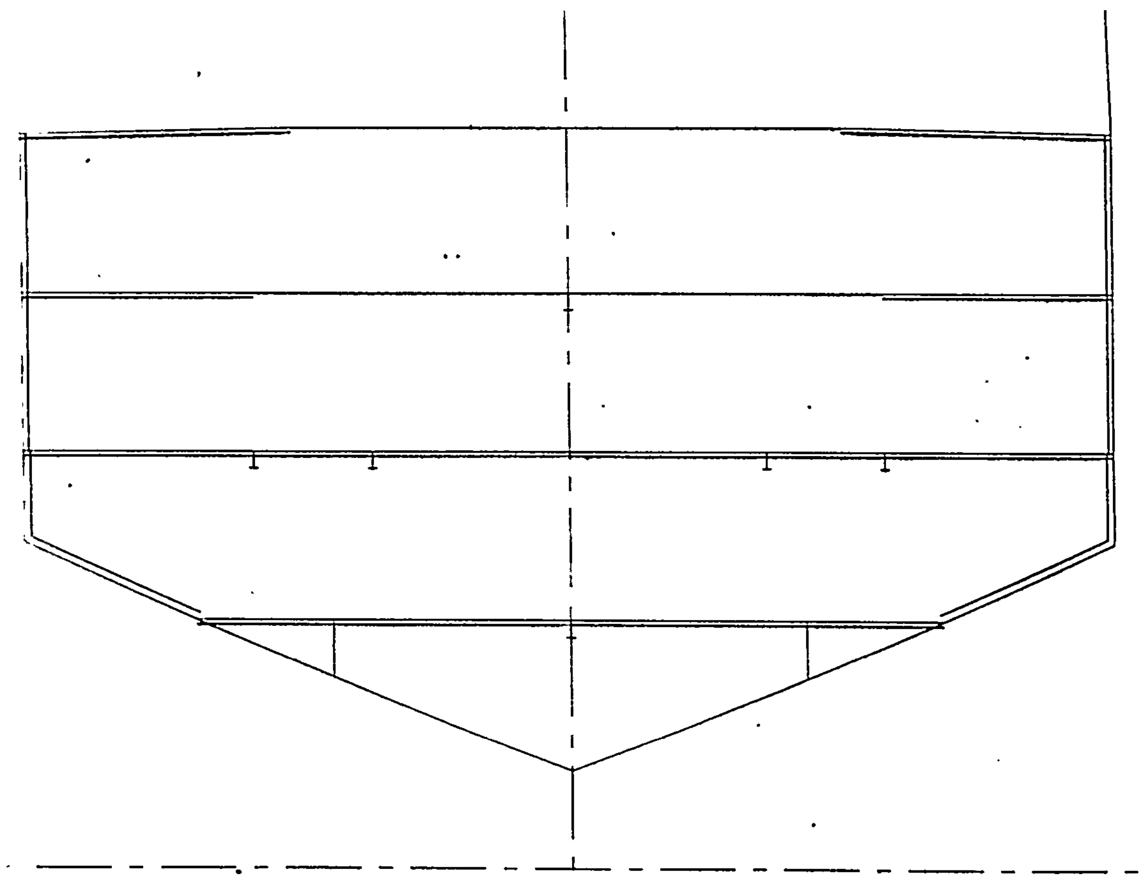
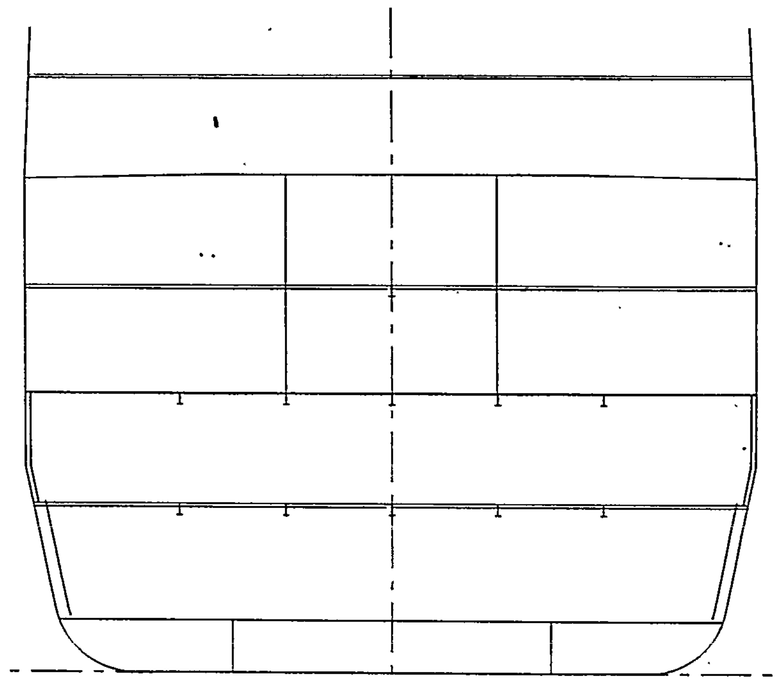


#16

FINAL LINES



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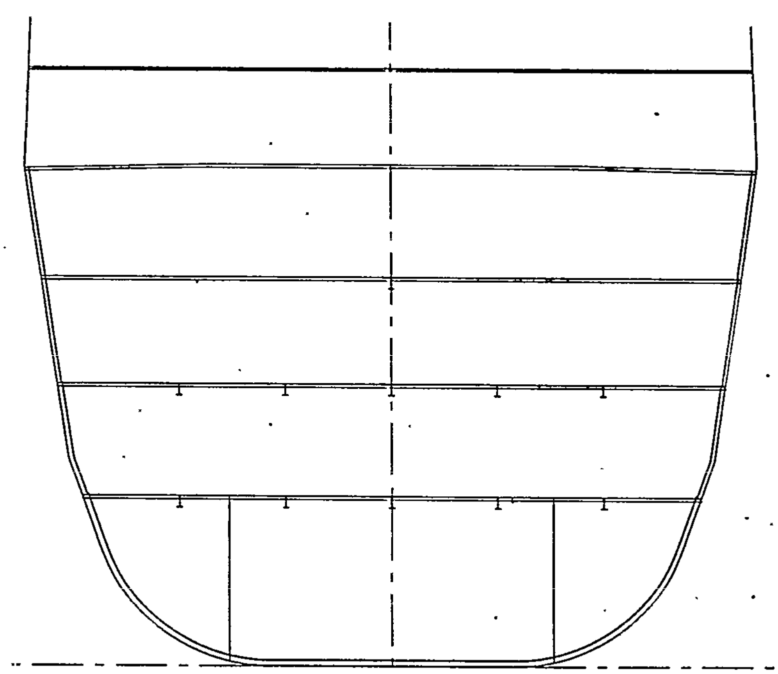
FINAL LINES



#90

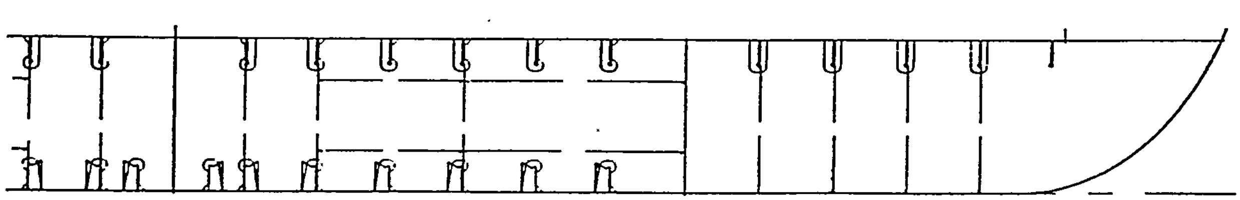
FINAL LINES

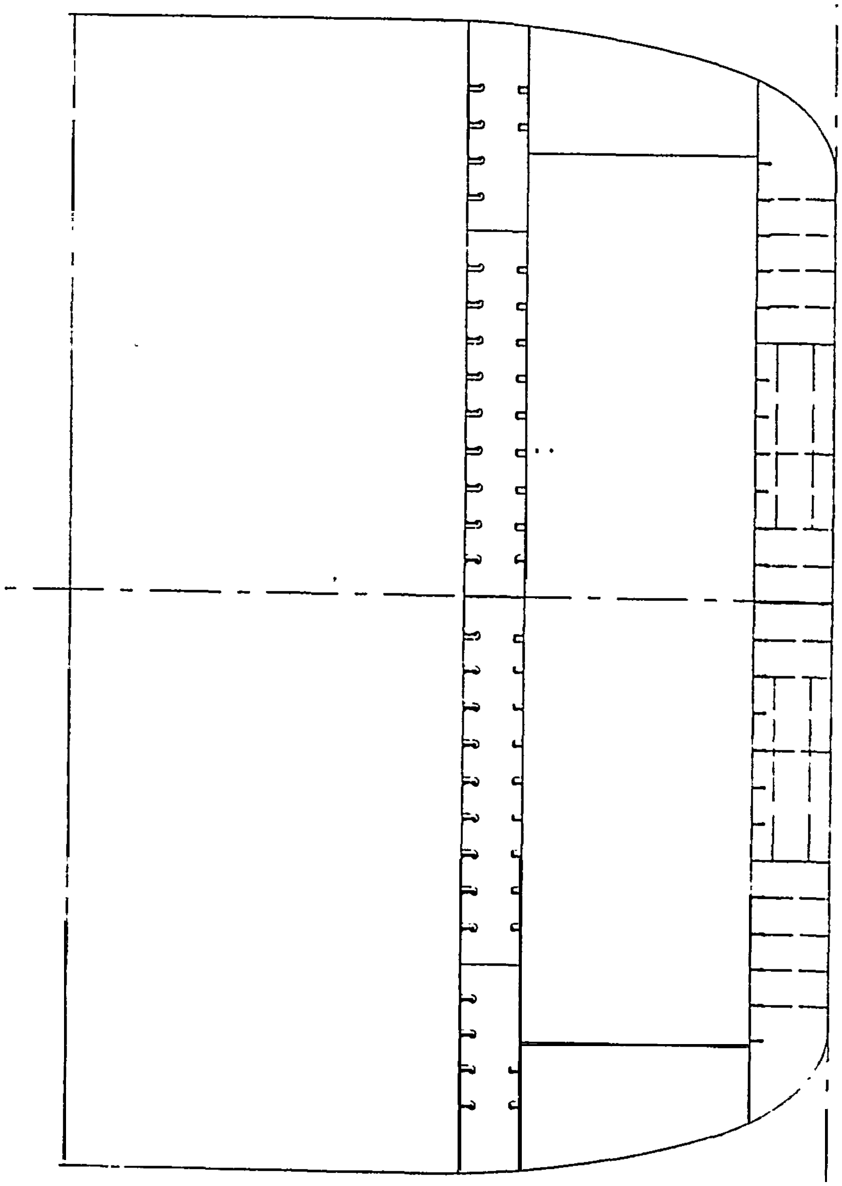
CASE STUDIES.

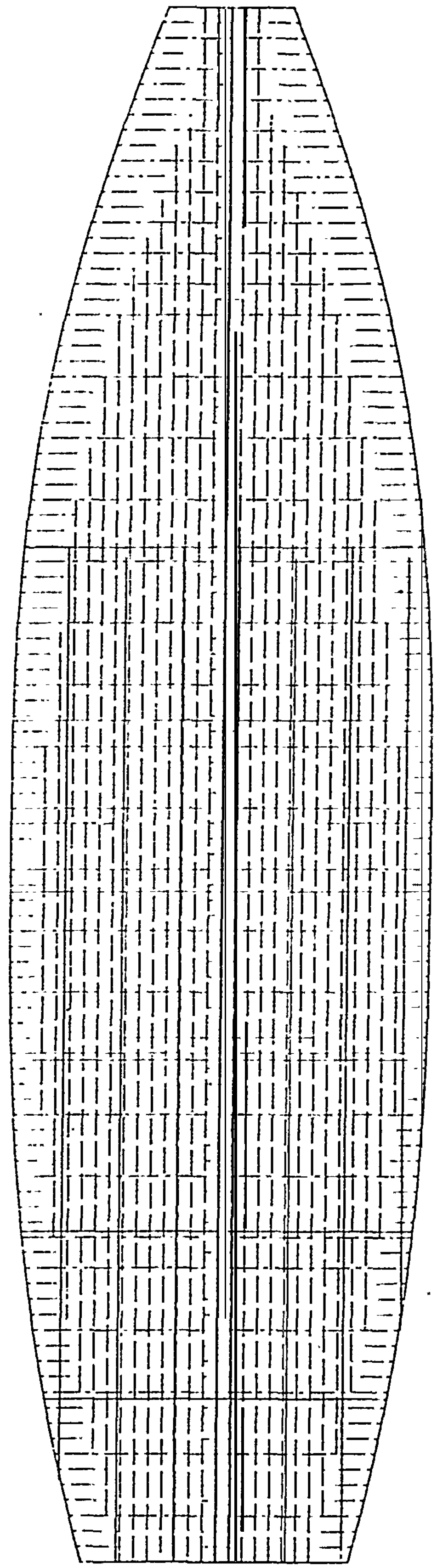
PAPER CARRIER
Main - dimentions:

Length over all_______________________ 114.4 M
Length betw.perp._____________________ 106.4 M
Bredth moulded_______________________ 18.99M
Depth moulded 1st. deck______________ 12.6 M
Depth moulded 2nd. deck______________ 5.9M
Max draft______________________________ 5.9M
Cb____________________________________ 0.662
- -

SRS scope of work for this project:
Create setteup for workingdrawings.
This were deliwerd to the shipyard drawing office for completion with texting etc.







C A S E   S T U D I E S

Box structures

Superstructures

Hatch covers

For all the other cases, we had a shipshape structure, and why not test it out on the simplest structure? A box shaped vessel or anything which are box shaped.
TRALOS and TRADET are dependent on framenumbers so we have made a database which are boxshaped in Alkon.

By doing this, we needed not to use Bof or Lanski.

The result can be seen on the following drawings.

Input time for this result were 5 hours.

```
DO YOU WANT TO CONTINUE (OR SKIP) (Y/N/SK) ........ I Y
ALL ● PARAMETERS SAME AS BEFORE? (Y/N) . . . . . . . . . . . . . ? Y
PLACE CROSSHAIR, TYPE A CHARACTER. 'C' WILL ALSO CLEAR SCREEN
DO YOU WANT TO CONTINUE (OR SKIP) (Y/N,SK) . . . . . . . I Y
ALL PARAMETERS SAME AS BEFORE? (Y/N) .................. ? Y
PLACE CROSSHAIR TYPE A CHARACTER. 'C' WILL ALSO CLEAR SCREEN
DO You WANT TO CONTINUE (OR SKIP) (Y/N/SK) ............ l Y
ALL PARAMETERS SAME AS BEFORE? (Y/N) ........................ ? Y
PLACE CROSSHAIR TYPE A CHARACTER 'C' WILL ALS0 CLEAR SCREEN
DO YOU WANT TO CONTINUE (OR SKIP) (Y/N/SK).... . . . .. 1
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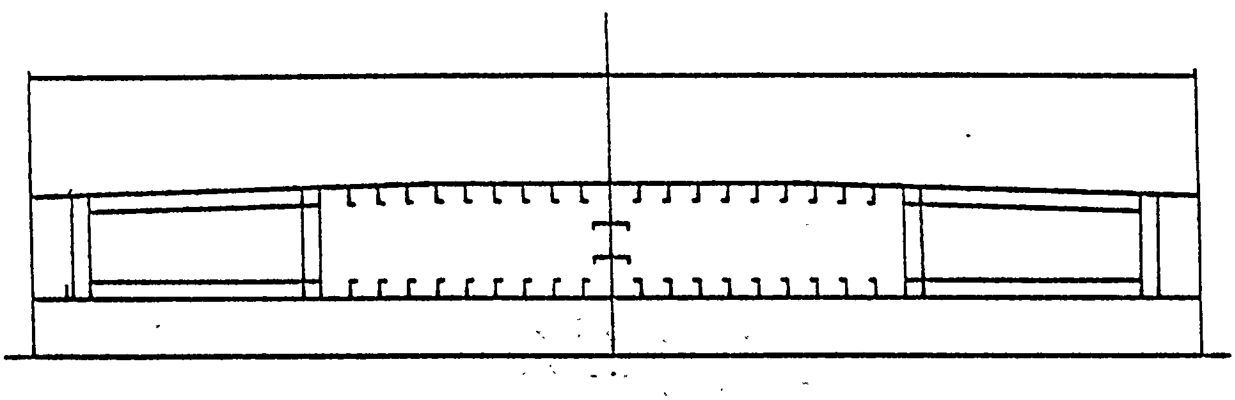
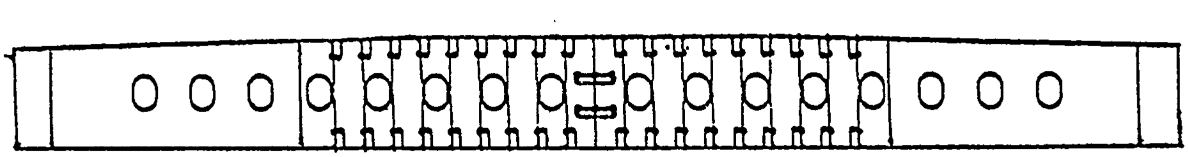
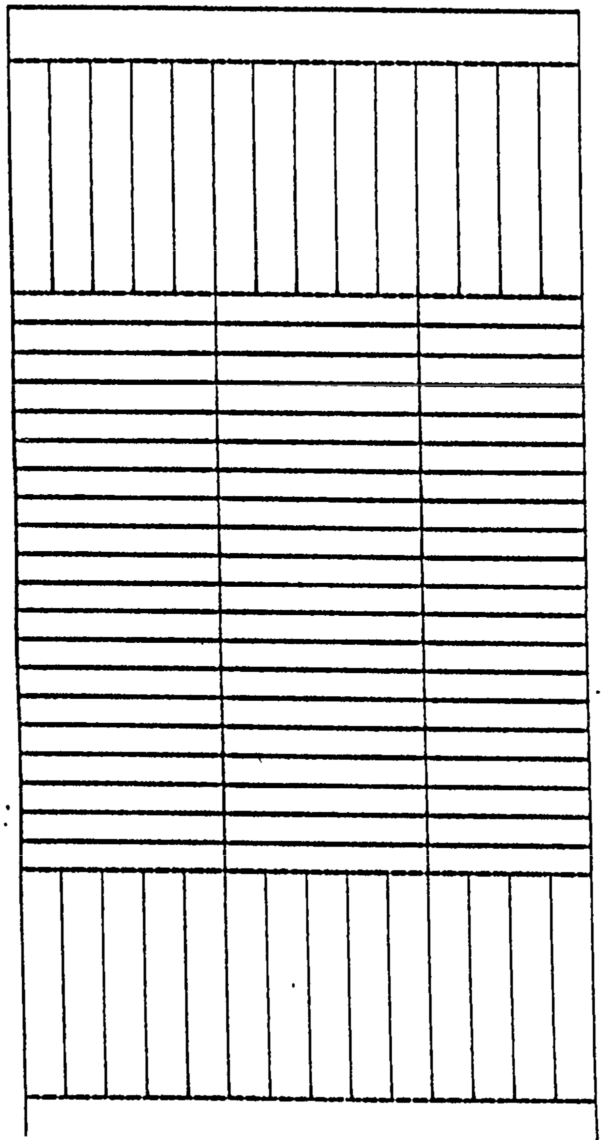
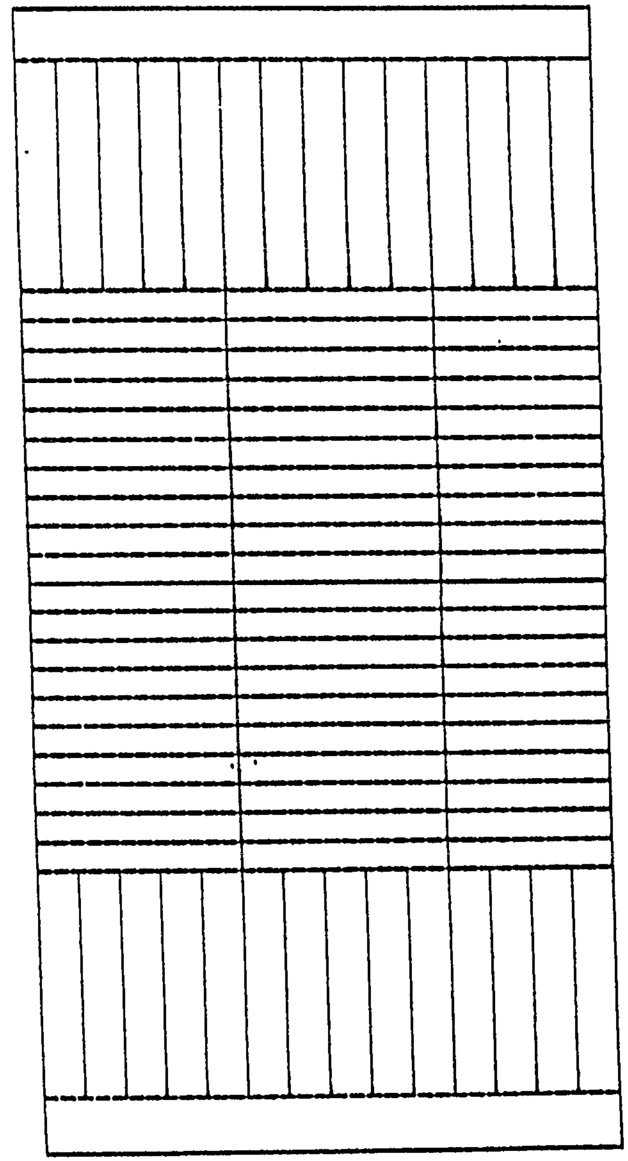




DO YOU WANT` TO CONTINUE (OR SKIP) (Y/N/SK) .... I Y
ALL PARAMETERS SAME AS BEFORE? (Y/N)
PLACE CROSSHAIR, TYPE CHARACTER. 'C' WILL ALSO CLEAR SCREEN
DO YOU WANT TO CONTINUE (OR SKIP) (Y/N,SK) I



PLACE CROSSHAIR, TYPE A CHARACTER. ‘C’ WILL ALSO CLEAR SCREEN
DO YOU WANT TO CONTINUE (OR SKIP) (Y/N/SK) . . . . :



A DESIGNERS WORKING PLACE

The situation have changed considerably the last years for the staff in the drawing office.
The manhour cost is increased compared with computercosts.
So one way to increase the efficiency and accuracy of the designer is to invest money in hardware and software.

In our office we will have working station (Alpha nummerical screens) for each designer. He will do the input for structural drawings on his own place.
Also an Hewlett Packard 45B topdesk computer, will be sheared between working places. This is also acting as a tereminal to our Prime 750. On this H.P. 45B most project work and strength calculations can be done.
Also checking of drawings on the graphic screen is possible.

After this checking the drawings or drawn out in the wanted scale on a calcumpplotter.

This equipment will of course increase the cost of a designeres working place, but compared with all dead time in running batch systems, I think this type of investment is recommendable. •

CONCLUSIONS

It is possible to save manhours with this system from 10% to 10% depending on the skillness of people, and the tools which are given to the designer.

The system is also more suitable for some special vessels.

Eg. tankers, (lot of longitudinal numbers)
Passenger vessel with lot of decks
Ro-Ro vessels.
I.e. vesse1s.with repeating items in the structure.

As the system is working now, there is information which could be better utilized.
I am thinking of steel specification of plates and profiles.
(Now we get profile length and seam length).
This can be coupled to a material program and that means we can have a preliminary steel specification on a very early stage.
For lofting some information in the system can be used but this is only minor parts. When this part of the system is linked together with Autopart and Autonest, we really have a system covering a vessel from project stage to production stage.

JAPANESE TECHNOLOGY THAT COULD IMPROVE U.S. SHIPBUILDING PRODUCTIVITY

James R. Vander Schaaf
Senior Naval Architect
IIT Research Institute
Chicago, Illinois

Mr. Vander Schaaf is responsible for the specification, development, training, and implementation of certain REAPS CAD/CAM products. He has IO years of experience in the development and application of various computer aided ship design and construction applications in use in government and industry.

Mr. Vander Schaaf holds degrees in aerospace engineering, naval architecture and marine engineering from the University of Michigan, and a degree in computer science from Johns Hopkins University.

ABSTRACT

This presentation highlights various aspects of Japanese Shipbuilding practices with emphasis on those of Ishikawajima-Harima Heavy Industries (IHI). Topics discussed include zone planning and outfitting, design and material definition and shipbuilding standards and modules.

FOREWORD

This presentation on Japanese shipbuilding methods and practices is based on a report[1] (the text of which follows) resulting from a visit to six Japanese shipyards by a team of six individuals with broad shipbuilding experience. The intent of this visit was to identify and examine low-investment high-return Japanese shipbuilding technology. The objective of the report was to encourage U.S. shipbuilders to adopt the observed advanced techniques for the purpose of improving productivity.

Information used in this presentation was also extracted from other sources, notably "Outfit Planning" [2] and "Improved Shipyard Production with Standard Components and Modules" [2].

[1] "Japanese Technology that could Improve U.S. Shipbuilding Productivity", J. R. Vander Schaaf, IIT Research Institute; P. E. Jaquith, Bath Iron Works; L. D. Chirillo, Todd Pacific Shipyards Corp; C. S. Jonson, Science Applications; J. J. McQuaid, National Steel & Shipbuilding; E. L Peterson, Peterson Builders Inc; National Shipbuilding Rerearch Program Publication, Maritime Administration, U.S. Department of Commerce, June 1980.

[2] References for these publications are contained at the end of this report.

1.0 INTRODUCTION

In January 1979 a study entitled, *Technology Survey of Major U.S. Shipyards* [l] [2] was completed and documented for the Maritime Administration (MarAd) by Marine Equipment Leasing (MEL), Inc. In the course of this survey the level of technology used by a cross section of U.S. shipyards was compared to the level of technology used by selected foreign shipyards. Japanese shipyards were included as a measure because of their preeminence in world shipbuilding. In conducting the study a major objective was to assist individual U.S. shipyards in the process of identifying those areas where the difference between U.S. technology and foreign technology is the greatest. A conclusion was that U.S. shipbuilding technology compared well in areas relating to modernized facilities and equipment, but was low in areas which are primarily management and methods oriented. In particular, nine of these critical areas[3] would require minor capital investment to raise the technology level significantly.

2.0 PROJECT OBJECTIVES

There are examples of successful transfer of Japanese technology to the U.S. shipbuilding industry such as for welding, automated pipe fabrication and other areas also requiring large capital investments. While this type of technology transfer is unquestionably valuable it was not the focus of this project.

Rather, the objective of this project was to identify and examine *low investment, high* return shipbuilding technology (e.g., methods, procedures, management and organizational techniques), placing emphasis on the critical areas cited in the MEL report. This examination was made by a team of individuals having broad shipbuilding experience in order to:

1. Identify specific techniques or methods,
2. Prioritize their values, and
3. Outline a plan for making them available to U.S. shipbuilders in the most efficacious manner.

3.0 PROJECT TEAM

The U.S. team formulated for this project consisted of the following six individuals:

Louis D. Chirillo
Todd Pacific Shipyards Corp.

Peter E. Jaquith
Bath Iron Works Corp.

Charles S. Jonson
Science.Applications, Inc.

John J. McQuaid
National Steel & Shipbuilding Co. (Retired)

Ellsworth L. Peterson
Peterson Builders, Inc.

James R. Vander Schaaf
IIT Research Institute (Project Director)

Summary resumes of these individuals are included in Appendix B.

4.0 JAPANESE YARDS VISITED

The shipyards were selected based upon IITRI contacts with the leading shipbuilding companies in Japan and their expressed interest to participate in this project. The following were visited during the period from October 29 through November 16, 1979 :

1. Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI)
   - Kure Shipyard
   - Aioi Shipyard
   - Tokyo Shipyard
2. Mitsui Engineering&Shipbuilding Co., Ltd.
   - Tokyo Head Office
   - Chiba Shipyard
   - Tamano Shipyard
3. Nippon Kokan Kabushiki Kaisha (NKK)
   - Shimizu Shipyard

With the exception of the Mitsui Chiba shipyard, all were old yards that had been modernized. All had under construction one to four ships of nonstandard design. Thus a good comparison could be made with U.S. practice.

It is also pertinent to note that in 1978, the Japanese Government requested that all shipbuilders reduce their facilities by 35 percent as a consequence of the worldwide oversupply of oil tankers. As a result, all of the companies visited have reduced their employment and/or have closed some of their new large shipyards. IHI closed its new Chita shipyard and NKK closed its most modern yard at Tsu.

[2] Numbers in brackets designate references at the end of this report.

[3] Extracted from the MEL report and presented as Appendix A of this report.

5.0 KEY OBSERVATIONS

Notwithstanding the reduction in shipbuilding capacity, shipbuilding production was high by U.S. standards. As an example, the Mitsui Tamano shipyard produced 9 ships (190,960 gross tons) and repaired 79 ships in 1978 with a total shipyard workforce of 3370 plus 2500 individuals from subcontractor organizations. In all yards, direct labor man-hour costs and construction schedules were approximately one-half when compared to U.S. practice.

5.1 Scheduling

- A typical milestone schedule for the construction of a new design nonstandard cargo, bulk, container or RO/RO Ship is as follows:

Contract award to start fab	- 6 Months
Start fab to keel	- 2 Months
Keel to launch	- 3 Months
Launch to delivery	- 3 Months
	14 Months

Further detail for this schedule is provided in Figure 5-1. A more detailed milestone schedule for a Mitsui bulk carrier is shown in reference 3, page 2-4.

- A typical IHI schedule for a 5200 ton destroyer is shown in Figure 5-2.
- In order to achieve the very short shipbuilding periods illustrated in these figures, Japanese shipbuilders have found it necessary to overlap” design, material procure-

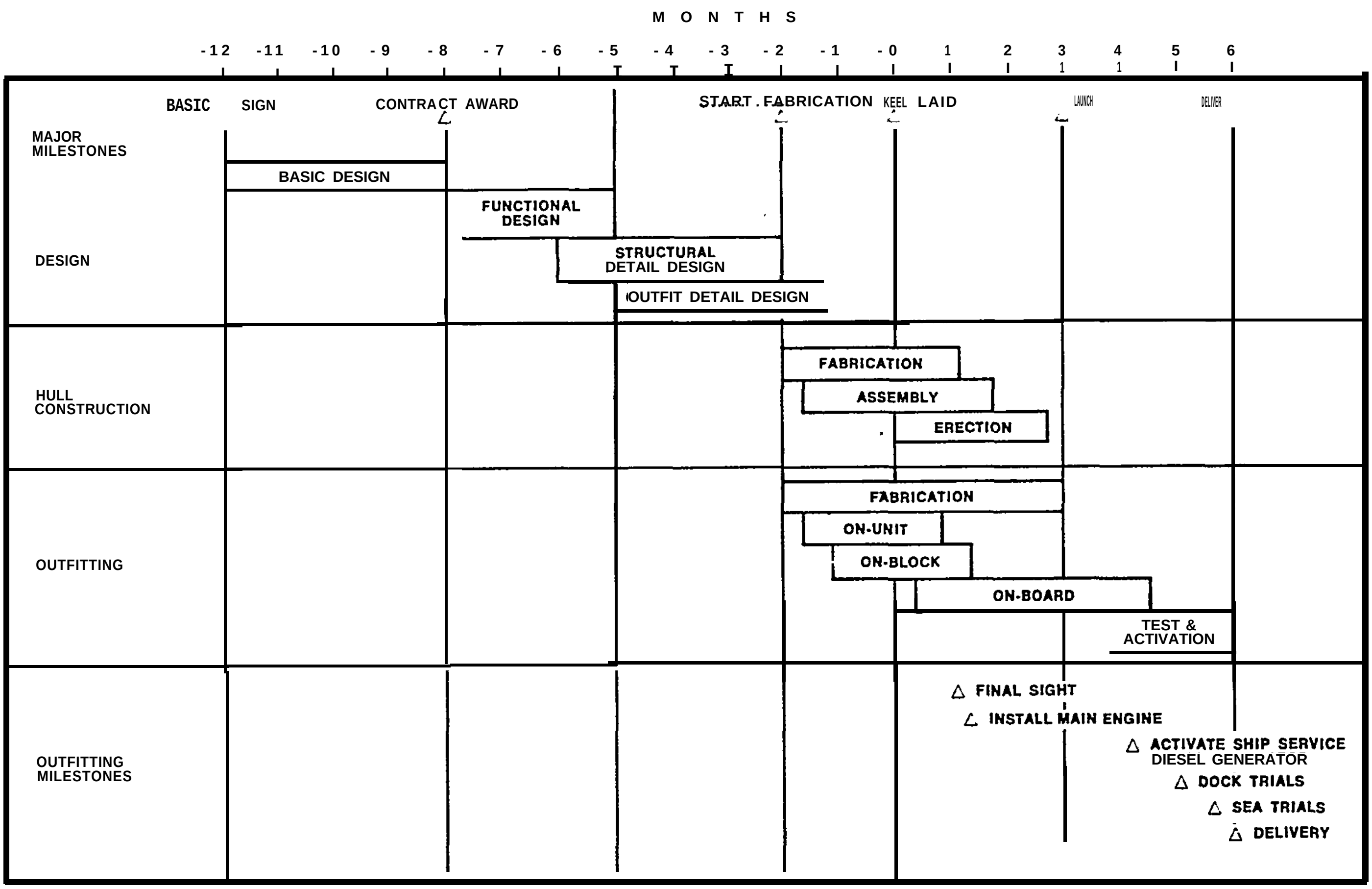


FIGURE 5-1: Major milestone schedule for commercial construction. It is typical with only minor adjustments for a new nonstandard cargo, bulk, container or RO/RO ship.

[4]Overlap of design, material procurement and production is facilitated with a product-oriented detail design, i.e., delineating zones on drawings and listing materials that are to be assembled for each zone at a specific stage of construction.

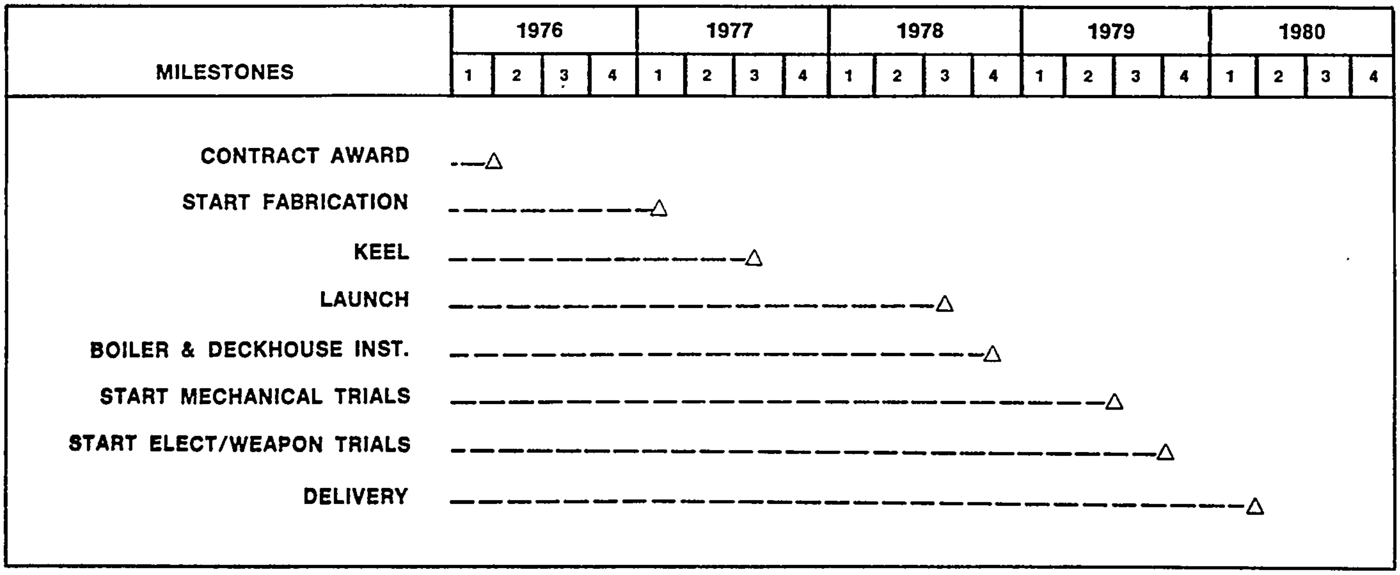


***FIGURE 5.*2**: Schedule for a IHI 5200 ton destroyer (DDH). It is typical for the first of a class having similar machinery to a previous class. Limited on-unit and extensive on-block outfitting were used on the first hull.

ment and production as illustrated in Figure 5-3 [2,4].

- Scheduling is simplified by early creation of a zone[5] sequence to coordinate design, material procurement and production.

- Shipbuilding schedules are normally Gantt charts or simple lists. IHI, Kure personnel, indicated that they had tried PERT/CPM networks and found them too inflexible for the shipbuilding environment. They did, however, indicate that they had used a computer network analyses system (PMS)[6] for the design and production of a floating power and pulp plant for the Amazon River. The reason given for using network analyses on the latter project is that their previous shipbuilding experience did not directly relate and they needed a more detailed analysis to identify critical paths and establish schedules.

- The schedule control mechanisms are simpler and in less detail than U.S. practice because work packages are smaller and reference material lists which are structured to reflect the required sequence for assembling the ship.

- Additional explanations and examples of shipbuilding schedules can be found in reference 3, pages 5-4 to 5-11, and in reference 4, pages 30 to 33.

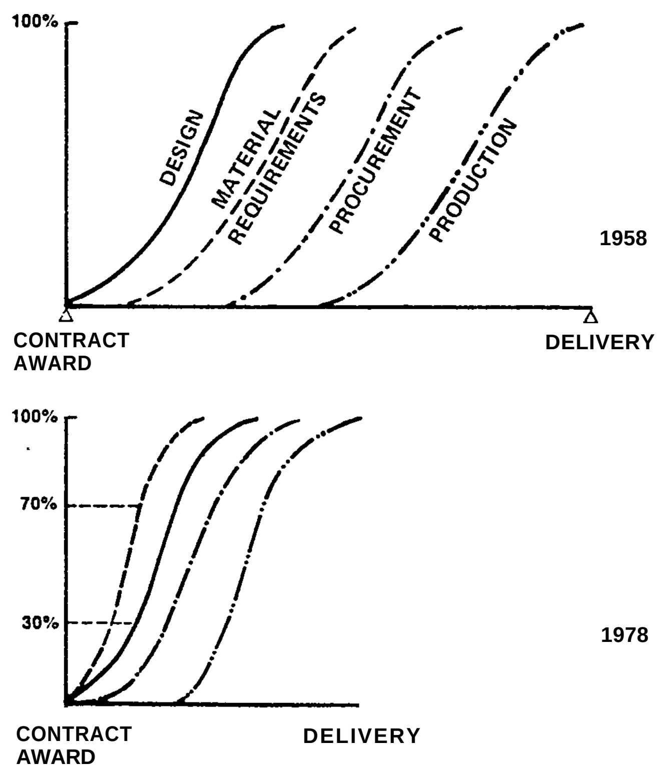


FIGURE 5-3: Overlap of design, material definition, procurement and production which has been achieved by the most competitive shipbuilders. When only 30% of a design is completed, 70% of its required material is defined.

[5] A zone is any three-dimensional subdivision of the planned ship which best serves for organizing information needed to support outfitting or steel construction at various stages (times).

[6] The Project Management System (PMS) developed by IBM, Inc.

5.2 Organization of Work

- The organization of work has been simplified by the product or zone orientation of both the design, and production organizations. A typical product or zone breakdown used with minor modifications in both design and production is as follows:
  - Hull Construction (Hull Fabrication, Assembly and Erection)
  - Deck Outfitting (Outfitting of Cargo and Deck Areas)
  - Accommodation Outfitting (Construction and Outfitting of Accommodation Spaces)
  - Machinery Outfitting (Outfitting of Machinery Spaces)
  - Electrical Outfitting (All Electrical Outfitting)

  This is shown for commercial shipbuilding in Figures 5-4 and 5-5 and for naval construction in Figure 5-6.

- Outfit Planning is a term used to describe the allocation of resources for the installation of components other than hull structure in a ship. Methods applied in Japanese shipyards have produced such benefits as [2] :

  1. Improved safety
  2. Reduced cost
  3. Better quality
  4. Shorter periods between contract award and delivery
  5. Adherence to schedules

- Three key features of the methodology are that the outfit design and planning functions are intimately linked, that they are linked because their principal product is the definition of modular, sometimes multi-system units called interim products, and that the design and planning of these units is controlled largely on the basis of geographical regions in the ship called zones.

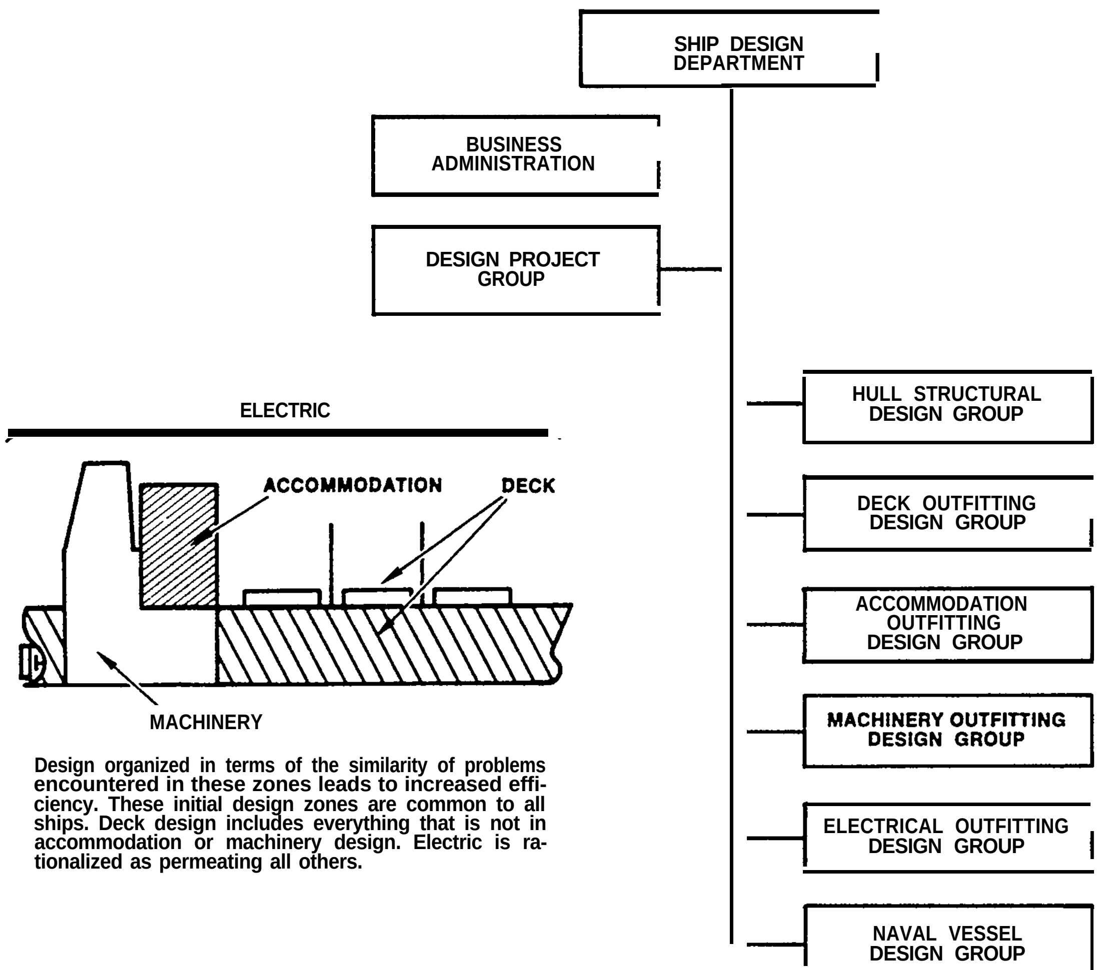


***FIGURE* 54: Organization** of the design department. IHI, KURE

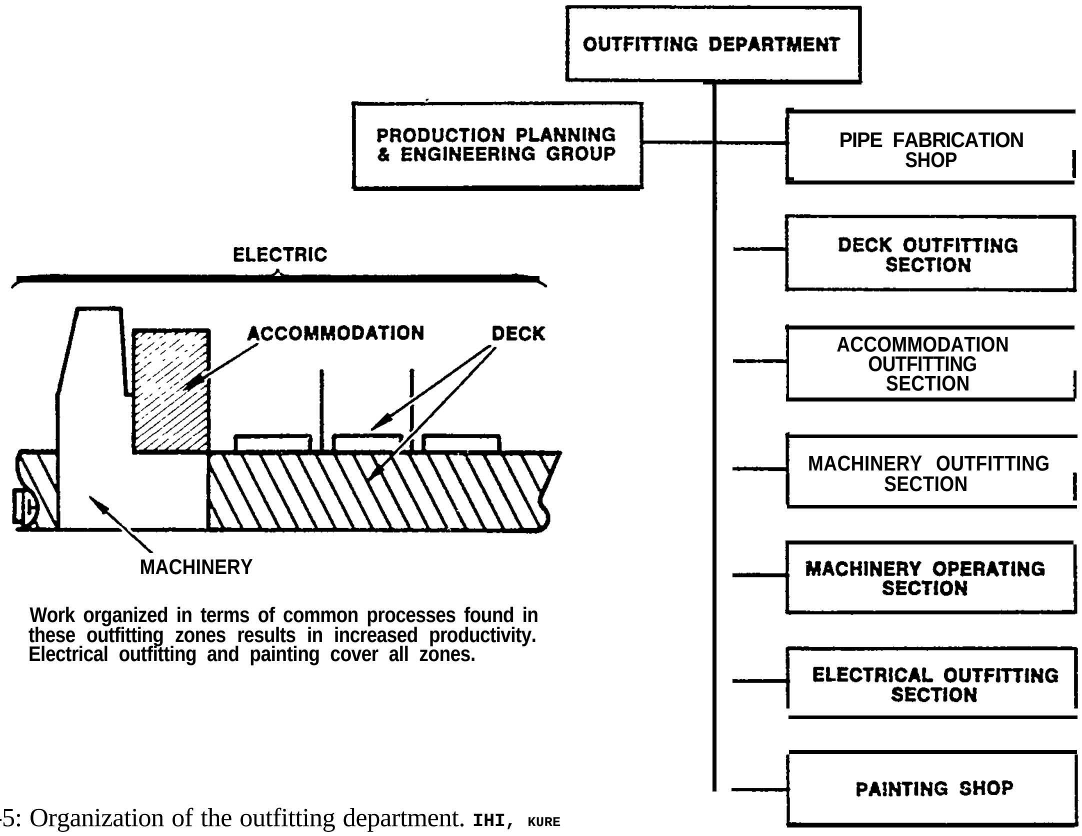


FIGURE 5-5: Organization of the outfitting department. IHI, KURE

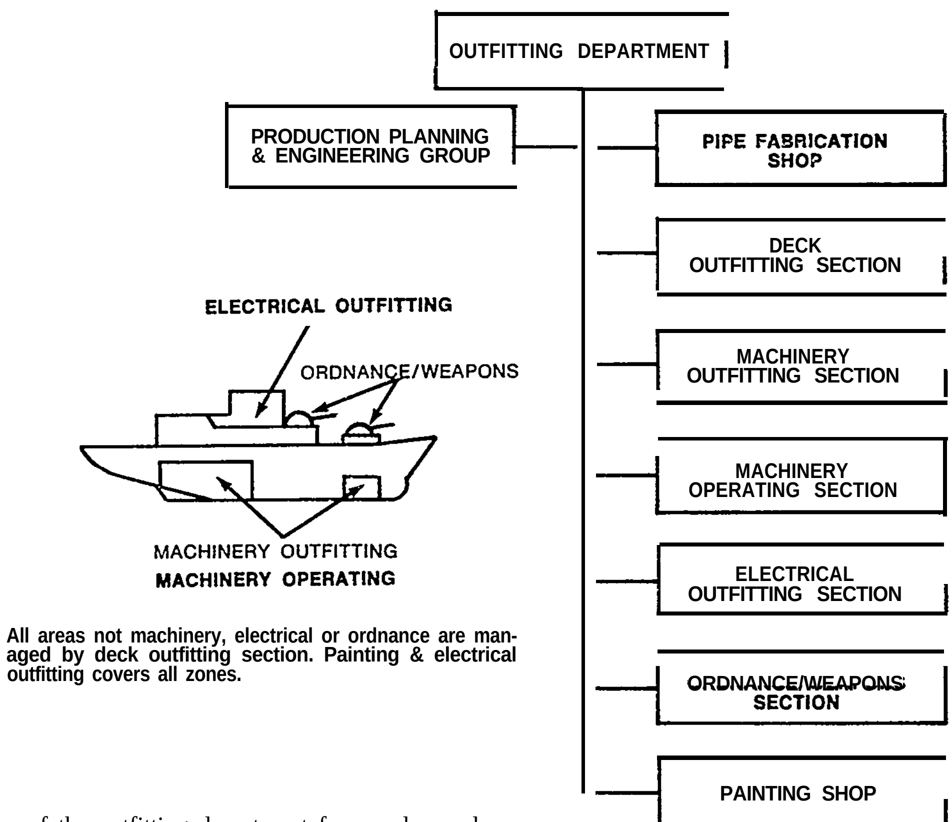
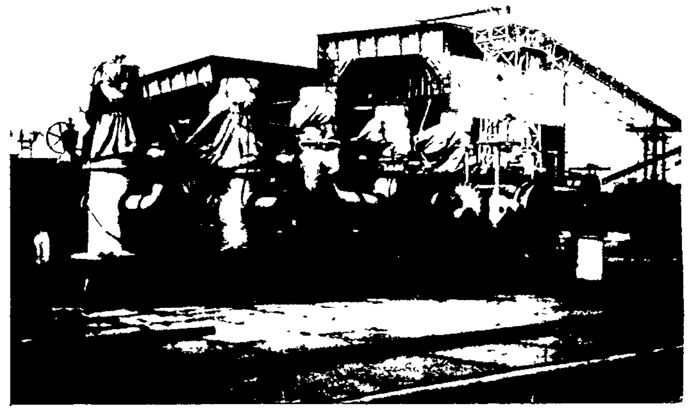


FIGURE 5-6: Organization of the outfitting department for naval vessels. IHI, TOKYO

- Zone outfitting, as contrasted with conventional outfitting by functional system, recognizes that certain multisystem interim products i.e., significant subassemblies of outfit materials, can be produced more efficiently away from hull erection sites. This approach allows most of the outfitting work to be accomplished earlier and in shops where it is safer and more productive. Outfitting, thus organized, is not a successor function to hull construction, but is accomplished simultaneously with it, and hence is free as much as possible from dependence on hull construction progress.
- Zone outfitting is divided into three basic stages listed by order of priority:

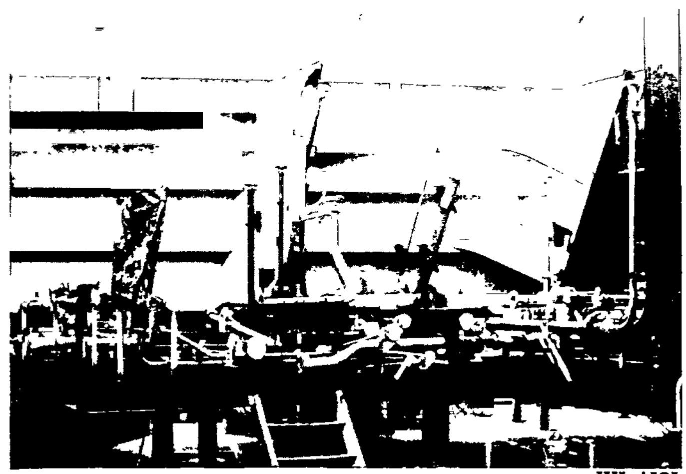
  1. On-unit
     The assembly of an interim product consisting of manufactured and purchased components not including any hull structure. On-unit outfitting is illustrated in Figures 5-7 and 5-8.
  2. On-block
     The installation of outfit components, which could include a unit, onto a hull structural assembly or block prior to its erection. On-block outfitting is illustrated in Figures 5-9 and 5-10.
  3. On-board
     Installation of any remaining outfit material and the connection of units and/or outfitted blocks. On-board outfitting is illustrated in Figure 5-11.

- The pallet concept is the method used to organize information to support zone outfitting. Literally a pallet is a portable platform upon which materials are stacked for storage and for transportation to a work site as shown in Figure 5-12. In production a pallet also represents a definite increment of work with allocated



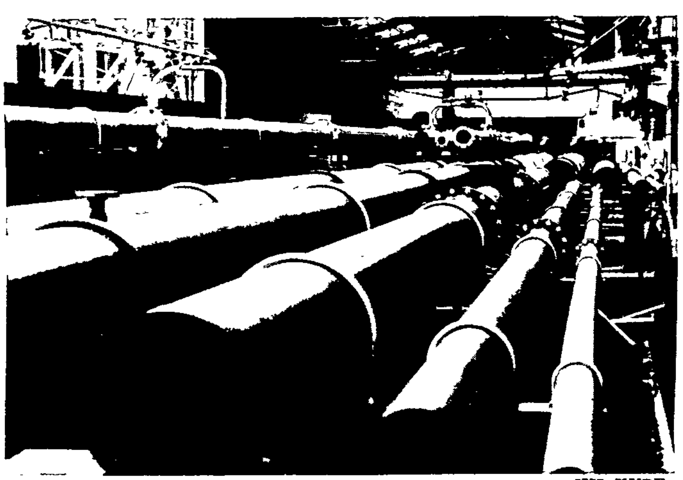
MITSUI, CHIBA

FIGURE 5-S: Example of on-unit outfitting. These units consist of significant subassemblies of various components.



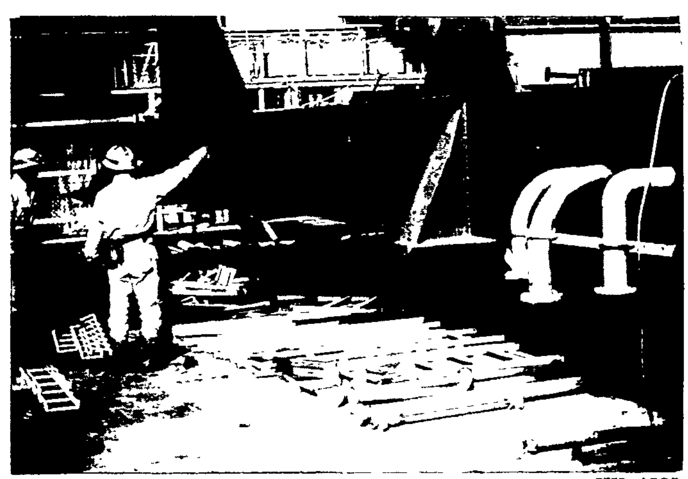
IHI, AIOI

FIGURE 5-9: Curved panel structural block outfitted upside down. Down-hand outfitting can significantly reduce manhours.



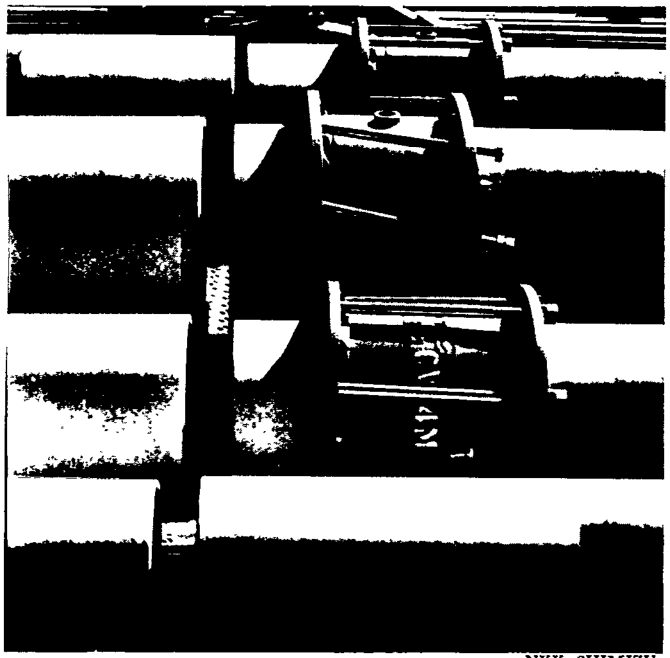
IHI, KURE

FIGURE 5-7: Example of on-unit outfitting. Such units are temporarily assembled together to insure that they will fit when landed on-board.



IHI, AIOI

FIGURE 5-10: Palletized material at site of on-block outfitting. For control purposes, pallets are typically limited to the assembly work one to three people can accomplish in one week.



NKK, SHIMIZU

FIGURE *5-11:* Connection of units on-board by the use of removable-stop type flexible couplings which can accommodate some misalignment.

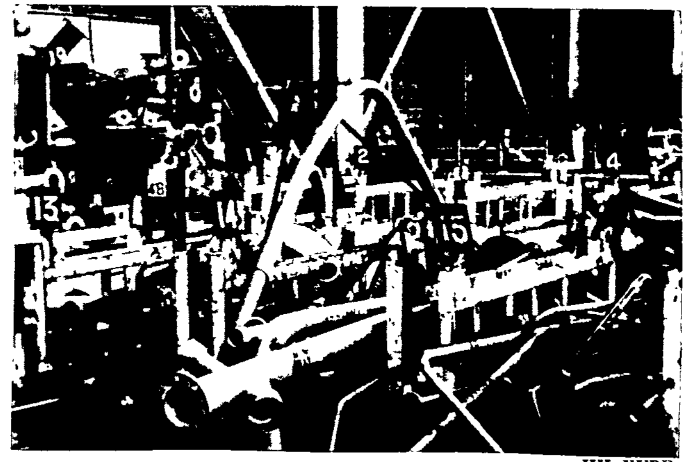


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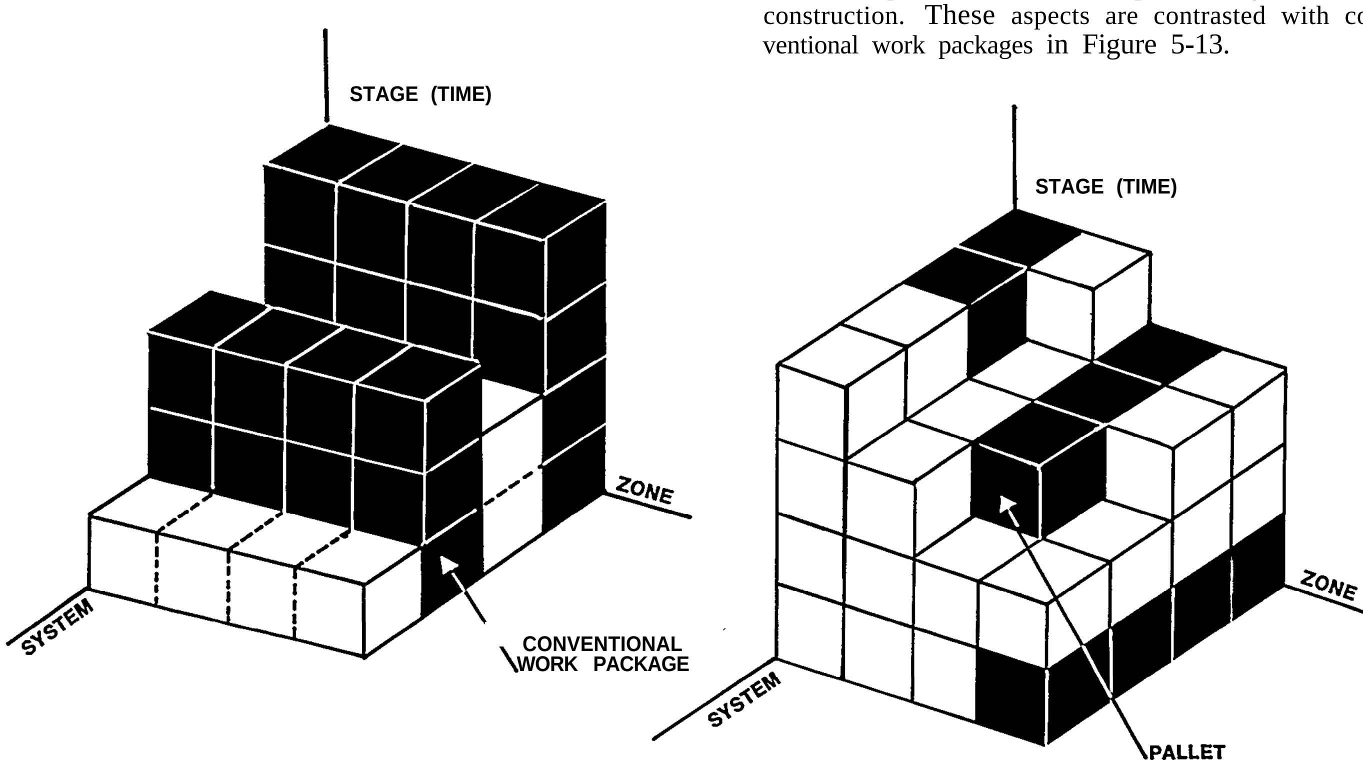
FIGURE 5-12: Outfit palletizing utilizes standard containers which may easily be handled by crane or forklift. In shipyards where zone outfitting is practiced, significant yard areas are devoted to sorting and storing (often on multi-tiered levels) palletized material.

resources needed to produce a defined interim product; hence it is a work package. In design a pallet is also a definition of components of the various functional systems in a particular zone at a specific stage (time) of construction. These aspects are contrasted with conventional work packages in Figure 5-13.



CONVENTIONAL OUTFITTING

Conventional system oriented work packages cross multiple zones and stages; therefore they do not reflect a product orientation.

ZONE OUTFITTING

Zone oriented pallets cross multiple systems but align directly to production work being accomplished by zone and stage (time) thus giving good control; production activities are exactly matched to the assembly sequence.

FIGURE 5-13: Conventional outfitting work packages contrasted with zone outfitting pallets.

5.3 Design and Material Definition

- Requirements for shortened periods between contract award and delivery have dictated an overlap of design, material definition and procurement, and production.[7] In order to achieve this overlap, design information is developed in less time, and, is structured in a manner which anticipates the requirements of material procurement and production.

- The design effort is divided into four successive stages [2]:

  1. Basic Design-e.g., specifications which establish performance requirements. It is more complete than U.S. practice.

  2. Functional Design-e.g., systems' diagrammatics developed from basic design. It includes simultaneous preparation of a material list, divided into unique material ordering zones, for each system diagrammatic. Functional design also includes preparation of other key drawings such as general, machinery and block arrangements.

  3. Detail Design-e.g., conversions from functional design to working drawings. This process yields composite drawings upon which work zones are delineated.[8] Certain material lists are initiated; these associate specific materials with specific work zones. The composites are sufficiently comprehensive so that details needed for manufacturing certain items, e.g., pipe pieces, may be derived. As they indicate the mounting positions of all components relative to each other, the composites are the basis for assembly instructions. The detail design stage also includes preparation of material detail design drawings, including their material lists, for items that must be custom fabricated such as pipe pieces, ladders and small tanks.

  4. Work Instruction Design-e.g., light-line contact prints, made from the composite drawings, on which only the components to be installed during a specific stage of construction are delineated by darkened lines. Thus, there can be more than one work instruction drawing per work zone. They are annotated with assembly instructions and each is accompanied by a specific material list per work zone per work stage. It is correct for designers to refer to each work instruction drawing and its material list as a pallet or work package. The work instruction design phase significantly overlaps the detail design phase and both are performed by the same people.

- During functional design, material lists are developed for all needed components and bulk raw materials by dividing the initial design zones (Figure 5-4) into three to seven "purchasing zones" that are used to facilitate accelerated procurement. These lists are called :

  MLS-Material List by (ship's functional) System (by purchasing zone).

- During material detail design, material lists for items which will be custom manufactured from raw materials are developed. Such lists are called:

  MLP-Material List for (manufacture of) Pipe (pieces)

  MLC-Material list for (manufacture of) Components (other than pipe) This is a list of subcontractor fabricated material such as ventilation ducting, walkways, ladders, etc.

- An additional material list is initiated during detail design and finalized during work instruction design. This is a list of material per pallet (work package) i.e., per work zone per work stage, for assembly of a specific interim product. There are three sources:

  1. Materials already incorporated in an MLS excluding the raw materials needed to custom manufacture other outfit materials.

  2. Custom manufactured components which are made from the raw materials identified in an MLP or MLC.

  3. Materials for which quantities are more exactly identified in working drawing preparation.

  Such lists are called:

  MLF-Material List for Fittings (per pallet, i.e., per work zone per work stage).

- The relationships of these material lists to design and to material procurement are illustrated in Figure 5-14. Material is ordered in progressive stages throughout the functional design, detail design, and work instruction design phases in order to suit material lead times. Long lead time material is ordered during basic design and sometimes prior to contract award.

- The use of these concepts to organize material requirements so that purchase and manufacturing orders can be placed as early as possible is a key element of high Japanese productivity.

[7]Mitsui personnel also indicated that on new ship design work, nearly all material would be defined when 30% of the total design man-hours had been expended.

[8]As an economic measure many work zones appear on one drawing. If a specific zone is very complicated, two or three drawings for one zone should be considered. The number of work zones per drawing is immaterial as long as the drawing issue schedule is derived from the pallet list.

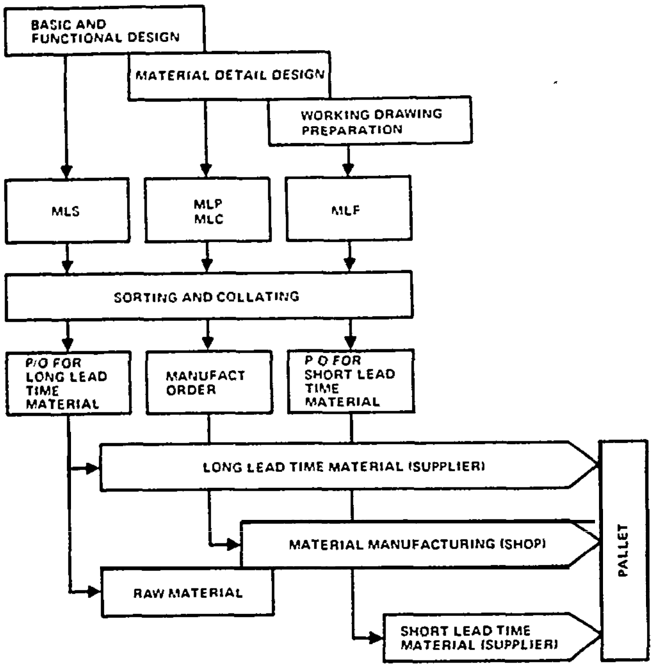
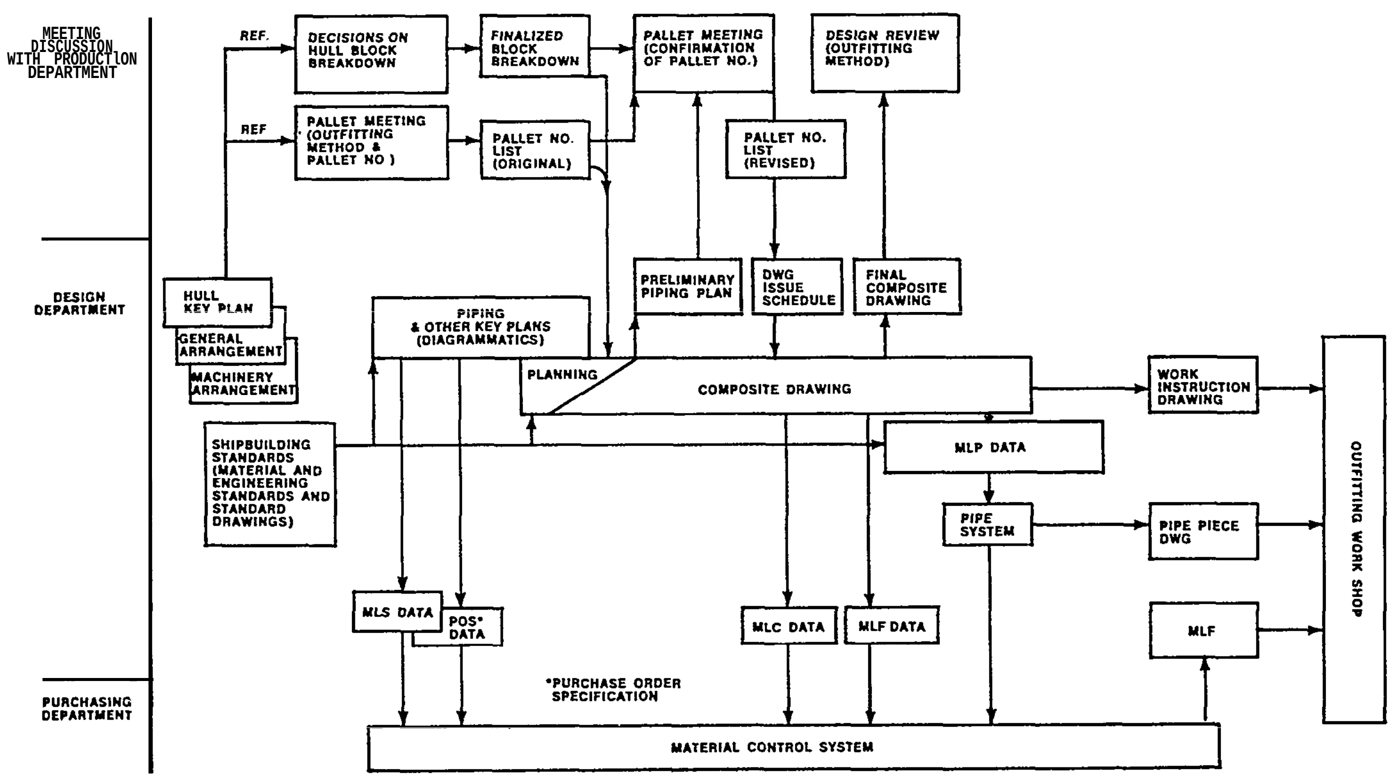


FIGURE 5-14: Relationships of material lists to design and to material procurement. Accuracy and timing of the sorting and collating functions are critical. In addition to sorting for long and short lead time and manufacturing-order materials, items identified in MLP, MLC and MLF must be compared to those in MLS. Also, the end product of each MLP and MLC must be accounted for in an MLF.

- Reference 4 pages 21 through 24 contains more detail concerning specifying and procuring materials through the use of standard classifications. These concepts are explained in detail in reference 2.
- The overall process of pallet design is illustrated in Figure 5-15. It is based upon intensive planning and production input early in the design process.
- Each of the basic outfitting stages, namely on-unit, on-block and on-board, are divided into the following substages to assist in the breakdown of work into pallets :
  1. On-block outfitting after a structural block is turned over for material pre-assembled into a unit.
  2. On-block outfitting for material pre-assembled into a unit.
  3. On-board outfitting for material pre-assembled into a unit.
  4. On-block outfitting for material to be installed piece by piece.
  5. On-block outfitting after a structural block is turned over for material to be installed piece by piece.
  6. On-board outfitting prior to an area being closed in by an overhead block.



Outline of the process of pallet design. Note that the drawing issue schedule is derived from the pallet list.

FIGURE 5-15: Outline of the process of pallet design. Note that the drawing issue schedule is derived from the pallet list.

7. On-board outfitting by zone or area prior to system tests (or other key events such as launch, trials, etc.).

8. On-board outfitting prior to launch.

9. On-board outfitting after launch.

10. On-board outfitting general category for items such as spare parts and touch up.

- The number of pallets which result for typical IHI standard vessels are shown in Figure 5-16. For control purposes, pallets are typically limited to the assembly work one to three people can accomplish in a week.
- The organization of pallets for an engine room lower level of a typical diesel machinery space consists of:

  -5 Structural Blocks
  -3 to 4 Pipe Units
  - 1 0 to 12 Machinery Units

- A sequence of zones by stages (a pallet list) provides the common documentation for design, material procurement, production, and control.

KIND OF VESSEL	ZONE \ STAGE	ON - UNIT: FOR LANDING ON-BLOCK	ON - UNIT: FOR LANDING ON-BOARD	ON BLOCK	ON-BOARD	TOTAL
FREEDOM MK-II 15,000 TON MULTIPURPOSE CARRIER	DECK	56	8	132	109	305
	ACCOMMODATION			34	408	442
	MACHINERY	30	49	66	107	252
	ELECTRICAL		44	90	82	216
	TOTAL	86	101	322	706	1215
FREEDOM 17,000 TON MULTIPURPOSE CARRIER	DECK		1	185	187	373
	ACCOMMODATION			24	285	309
	MACHINERY	17	45	32	227	321
	ELECTRICAL		19	11	52	82
	TOTAL	17	65	252	751	1085
FORTUNE 20,000 TON MULTIPURPOSE CARRIER	DECK		2	138	63	203
	ACCOMMODATION			69	159	228
	MACHINERY		81	35	110	226
	ELECTRICAL			33	88	121
	TOTAL		83	275	420	778
BULK CARRIER 60,000 TON	DECK	116	33	431	106	686
	ACCOMMODATION		2	87	239	328
	MACHINERY	18	78	32	144	272
	ELECTRICAL			46	173	219
	TOTAL	134	113	596	662	1505
BULK CARRIER 168,000 TON	DECK	94	44	515	112	765
	ACCOMMODATION		5	83	262	350
	MACHINERY	23	93	55	171	342
	ELECTRICAL			49	201	250
	TOTAL	117	142	702	746	1707
VLCC 250,000 TON	DECK	136	101	532	151	920
	ACCOMMODATION	18	5	58	234	315
	MACHINERY	5	106	84	208	403
	ELECTRICAL			40	196	236
	TOTAL	159	212	714	789	1874
VLCC 250,000 TON	DECK	124	83	487	139	833
	ACCOMMODATION	19	17	96	275	407
	MACHINERY	32	115	88	190	425
	ELECTRICAL			85	223	308
	TOTAL	175	215	756	827	1973

FIGURE 5-16: Number of outfit pallets (work packages) for IHI standard vessels.

- The use of the composite outfit arrangement drawing is a key element in the reduced working plan development time achieved by the Japanese yards versus U.S. practice. This is illustrated in Figure 5-17.
- Typical composite outfit arrangement drawings could be organized as follows:
  - -*Engine Room Lower* Level-Drawings include foundations; piping; grating framework, plating, and handrails; piping supports; and ladders.
  - -*Deck* Piping-Drawings include piping; grating framework, plating, and handrails; ladders; deck fittings: piping supports; and foundation installation.
  - --*Accommodations-Three* drawings could be used ; a) piping, ventilation, ladders, equipment and foundation installation; b) joiner installation and c) electrical installation.
- The outfitting composite drawings reviewed at all the shipyards were not sophisticated. The piping was shown as one line although the flanges appeared to be shown as double lines. The composite drawings did include elevations, sections and details and the drawings were coded with symbols or by shading to indicate the installation stage, i.e., on-unit, on-block, or on-board.
- Piping and other system diagrams are developed in schematic form by deck level similar to U.S. practice. Piping diagrams are complete in all respects and along with the machinery arrangements are the only piping drawings submitted for agency approval. The piping diagrams are used in conjunction with machinery arrangements to determine the pipe lengths for, the purpose of sizing and material calculations.
- Both functional and working plan development are greatly assisted through the use of comprehensive standards[9] and extensive experience on previous vessels.
- Typical structural working plans include deck, side shell, web frames, etc., for the complete block or for a group of similar blocks. Structural working plans do not include foundations which are issued on a separate book plan by zone.
- Additional explanations and illustrations of the Japanese design process can be found in reference 3, pages 3-1 to 3-8 and in reference 4 pages 7 through 11.

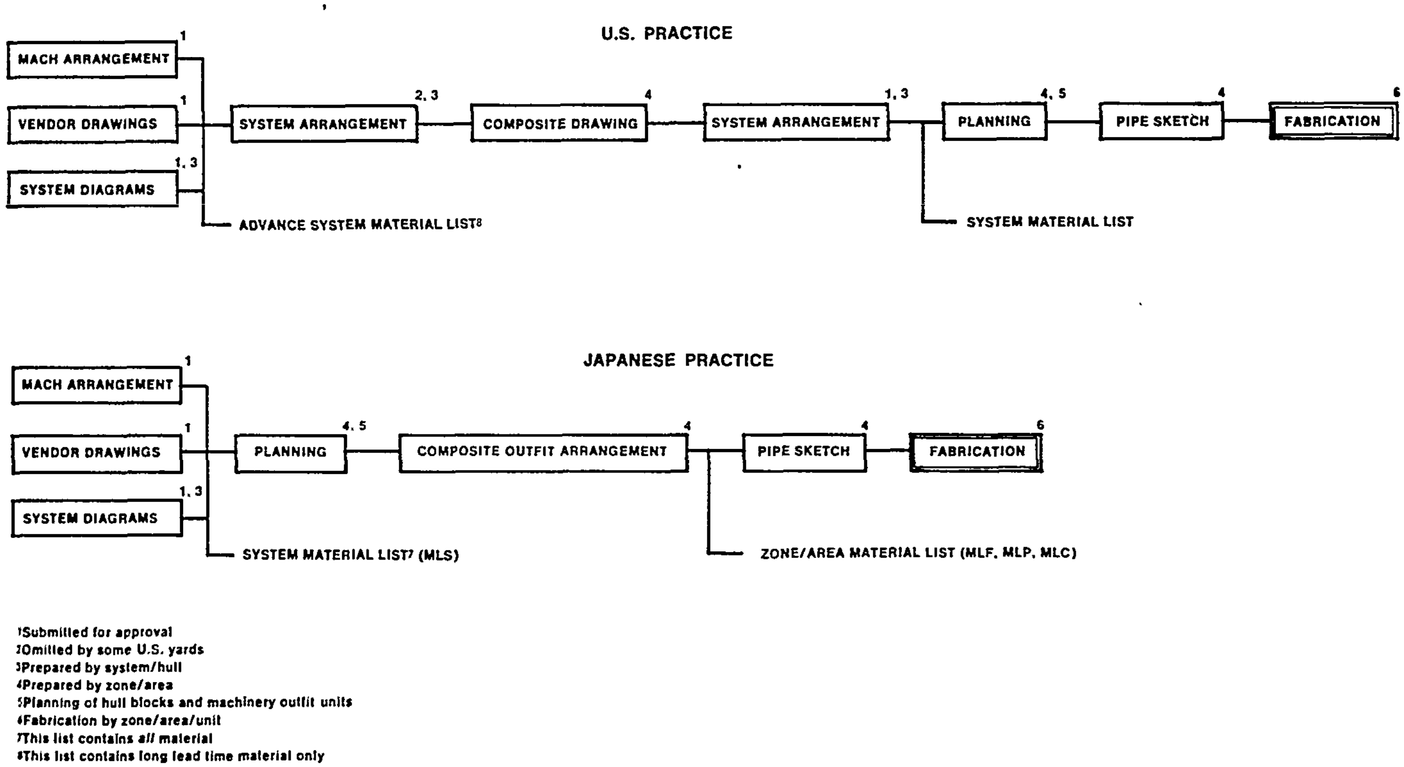


FIGURE 5-17: Flow chart of the process of outfit working plan development (U.S. contrasted with Japanese practice).

[9]Documented standards or guidance data for use in the areas of functional and detail design, planning, production and quality control.

5.4 Shipbuilding Standards and Modules

- Both IHI and Mitsui have developed extensive standards for use in functional design, detail design, planning, production and quality control. Figure 5-18 pro: vides a classification of IHI standards.
- According to IHI, Kure personnel, standards have been developed to reflect high quality based on new requirements and reflecting past experiences. The use of standards is sold to the owner, during technical negotiations prior to contract award, based on the principals of proven service experience, reduced delivery time and reduced cost.
- The use of standards and modules in this manner is a key element in the significantly reduced design and production costs and schedules achieved by Japanese shipyards versus U.S. practice. [5][10]
- The IHI design approach appears heavily oriented to the use of design standards which have been developed based on standard ship designs. See Figure 5-16 for examples of standard IHI designs. Although these design standards are based on standard ship designs, they have been developed with the idea of solving a range of problems versus solving the specific design problems presented by the ship being designed. Mitsui, on the other hand, bases their designs on previous ships having similar engine types and power ranges. Neither IHI nor Mitsui appear to have a totally comprehensive documented set of standards covering all ship types. Standards for tanker and bulk ships appear to be very thoroughly developed, while standards for liner ships are less completely developed.
- An example of vendor catalog items adopted as shipyard standards is illustrated by Figure 5-19. These

Classification of Standards			Nos.
BASIC STANDARDS (IS)	MATERIAL STANDARDS (SO)	Common components Hull fittings Machinery fittings Electric fittings	600 600 200 200
	Sub-total		1,600
	ENGINEERING STANDARDS (SOT)	Design process standards Production eng. process standards Inspection process standards	1,100 100 200
	Sub-total		1,400
STANDARD DRAWINGS (SD)	Machinery drawings (SD1)* Component and fitting standard drawings Other guidance drawings		1,200 350 350
	Sub-total		1,900
GRAND TOTAL			4,900

*SD1 are standards where a change must be the result of a mutual agreement between IHI and a vendor or subcontractor.

FIGURE 5-18: Classification of standards-IHI.

DRAIN PUMP (Large Size)						MACH. NO.	M O 23	
						TYPE	V E C	
CARGO PUMP CAP		m3/h x m	3500 x 125	4000 x 125	500 x 150 4000 x 150	4000 x 150	4500 x 150	5000 x 150
CARGO PUMP SETS		KW x rpm	3		3	4	4	4
CAPACITY		m3/h x m	70 x 90	80 x 90	90 x 95	110 x 95	130 x 95	70 x 100
MAKER A	MODEL NO.		EVZ 100	EVZ 130			EVZ 130-2	EVZ-130
	STAND DRWG. NO.	SDx	440011360A	440011380			440011390	440011380
	MOTOR CAPACITY	KW x rpm	37 x 1800	45 x 1800		55 x 1800	75 x 1800	45 x 1800
	MOTOR MODEL NO.							
	CAPACITY RANGE	m3/h x m	56~ 70 x 90	76~ 100 x 90	78~ 95 x 95	96~ 110 x 95	118~ 130 x 95	66~ 85 x 100
	WEIGHT PUMP	t						
	WEIGHT MOTOR	t						
MAKER B	MODEL NO.		200 x 100-2YCSE-A	250 x 125 - 2VCDS - A			300 x 150-2VCDS-A	250 x 125-2VCDS-A
	STAND. DRWG NO.	S D I	440021730A	440021740A			440021390	440021740
	MOTOR CAPACITY	KW x rpm	37 x 1800	45 x 1800		55 x 1800	75 x 1800	45 x 1800
	MOTOR MODEL NO							
	CAPACITY RANGE	m3/h x m	51~ 70 x 90	80~ 100 x 90	95 x 95	91~ 110 x 95	130~ 140 x 95	70~ 85 x 100
	WEIGHT PUMP	t						
	WEIGHT MOTOR	t						

DRAIN PUMP (Mid Size)						MACH NO	M O 23	
						TYPE	V E C	
CARGO PUMP CAP		m3/h x m	3500 x 125	4000 x 125	3500 x 150 4000 x 150	4000 x 150	4500 x 150 5000 x 150	5000 x 150
CARGO PUMP SETS		KW x rpm	3		3	4	4	4
CAPACITY		m3/h x m	40 x 90	50 x 90	50 x 95	60 x 95	70 x 95	70 x 100
MAKER A	MODEL NO		EVZ 100					EVZ 130
	STAND DRWG. NO	SD1	440011360A					440011380
	MOTOR CAPACITY	KW x rpm	30 x 1800			37 x 1800		45 x 1800
	MOTOR MODEL NO.							225 M
	CAPACITY RANGE	m3/h x m	40– 55 x 90		50 x 95	51– 70 x 95		66 85 x 100
	WEIGHT PUMP	t						
	WEIGHT MOTOR	t						
MAKER B	MODEL NO.		200 x 100 - 2VCSE-A					250 x 125 2VCDS-A
	STAND. DRWG NO.	S D 1	440021730					440021740
	MOTOR CAPACITY	KW x rpm	30 x 1800			37 x 1800		45 x 1800
	MOTOR MODEL NO							
	CAPACITY RANGE	m3/h x m	40– 50 x 90		50 x 95	51~ 70 x 95		70~ 85 x 100
	WEIGHT PUMP	t						
	WEIGHT MOTOR	t						

***FIGURE* 5-19:** Examples of machinery component standards IHI. Machinery is selected from standard models of two or more proven manufacturers which have been pre-approved by the shipyard and registered as standard equipment.

[10]Reference 5 by Y. Ichinose, IHI contains a detailed description of IHI standards and modules.

standards have been developed to a range of requirements instead of being designed around a specific ship type. Designers using these standards do not have to wait for vendor furnished information to complete detail design tasks, such as foundation design illustrated by Figure 5-20.

- Both IHI and Mitsui have single main engine vendors for both low speed and medium speed diesel. IHI manufactures the low speed Sulzer and medium speed Pielstik engines while Mitsui manufactures the low speed B&W and medium speed Mitsui engines.
- Design and material standards start at the level of individual components and pieces of raw material and include progressive tiers to the level of standard machinery arrangement modules (see Figure 5-21) and system diagrams. They apply to various ships and various sizes of standard steam or diesel power plants.
- Functional design standards for a 60,000 ton bulk carrier engine room design[11] included the following:
  - -Engine Room arrangement based on a single engine type with alternative number of cylinders.
  - -Machinery arrangement including plan, elevation and section.
  - -A list of key equipment including alternate vendors except for the main engine.
  - -All system diagrams.
  - -An arrangement of outfitting units.

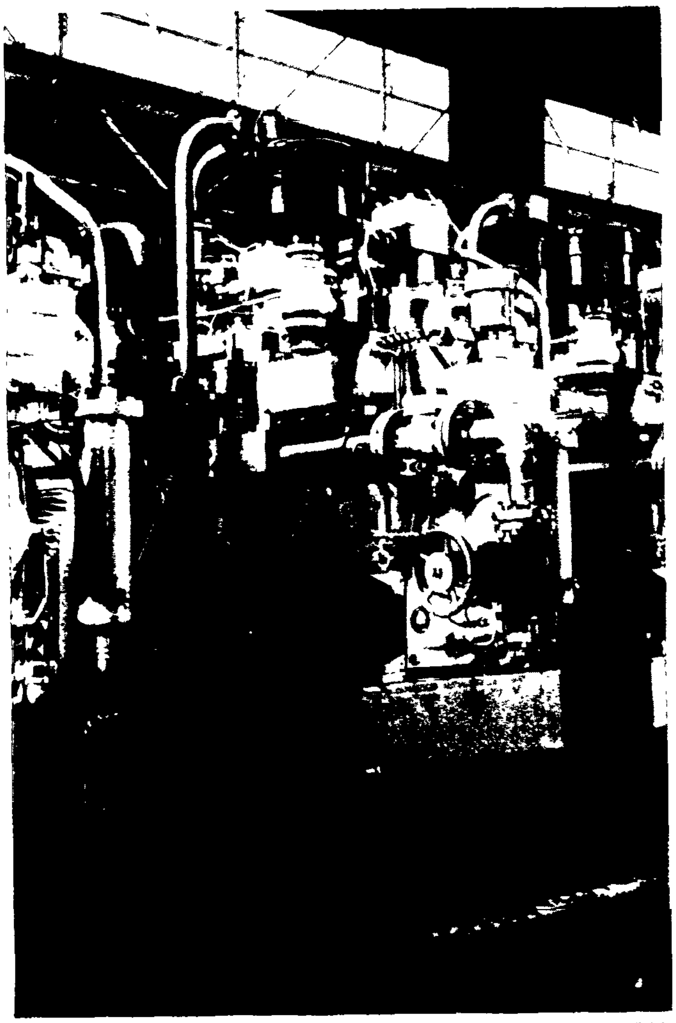


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FIGURE 5-20: Standard diesel generators with subcontractor provided foundations and some piping attached,

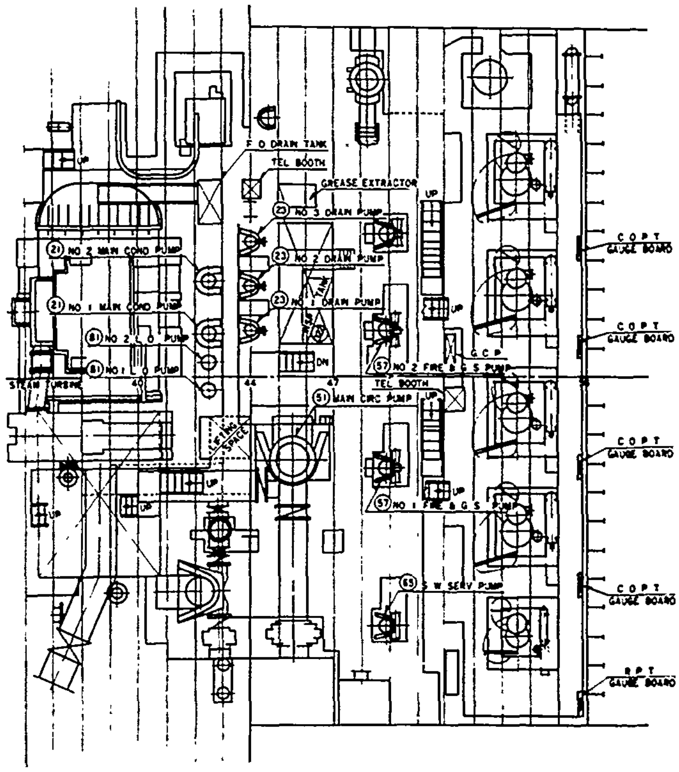

FIGURE 5-21: Each position in a reusable machinery arrangement has enough space around it to accommodate the several catalog items that are maintained in the standards file for that position. Pipe detail designers adjust for the different nozzle locations.

[11]The majority of machinery units or outfit packages shown for this design were based on standard machinery modules which are system oriented. Examples are lube oil purification, fuel oil treatment, jacket water heat exchangers, etc.

-Machinerv module designs (each consisting of a reusable diagrammatic and its machinery and piping arrangements and parts list)

- The design of system modules using functional design standards is illustrated in Figure 5-22. In this case, the design standards have allowed for alternative system capabilities and the designer selects from these alternatives to create the functional and working drawings for a new ship design. The basic elements used in these modules are the standard machinery components.
- IHI personnel indicated that they have previously forwarded to the MarAd Standards Program Manager, at Bath Iron Works, a proposal for technical assistance in the area of standards development. This proposal should be carefully reviewed, although, at this point, Mr. Hamada of IHI, indicates that the question of selling IHI standards or assistance in standards development is being reconsidered by IHI top management.
- Mitsui design standards, in the form of design manuals and design check lists, were reviewed. These design standards provide substantial guidance to designers in the form of partial system diagrams, tables or graphs simplifying engineering calculations, check lists of items required to properly complete functional or working drawings, check lists of items required to ensure reduced costs in the production area and check lists, based on experience, of items causing either production problems or problems in the guarantee area.
- This approach to standards has provided these shipyards a formalized way of documenting their experience. Further it permits developing new design or production procedures in a manner that facilitates their adaptation to new owner or service requirements.
- Additional explanation and examples of Japanese practice in the area of shipbuilding standards can be found in reference 3, pages 3-7 to 3-l 6, and reference 4 pages 14 through 19.
- Although IHI appears to have moved further in developing comprehensive shipbuilding standards, both Mitsui and IHI should be considered as potential subcontractors for the development of a comprehensive standards program.

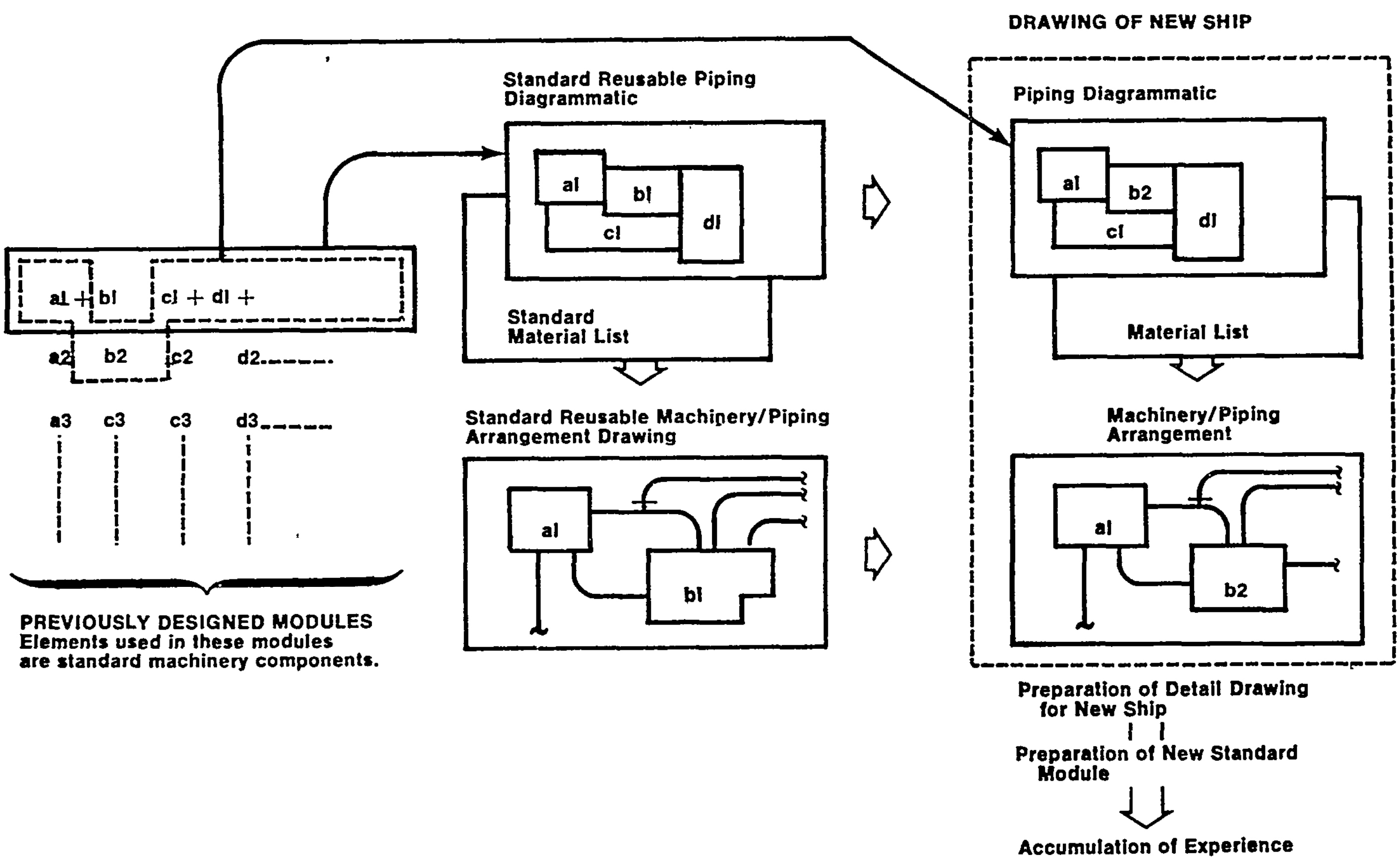

FIGURE 5-22: Flow chart of system module design (IHI) .

5.5 Outfitting Approach

- On-unit outfitting offers the greatest potential for improving overall shipbuilding productivity as compared to the other two outfit methods i.e., on-block and on-board. Hence primary emphasis is placed on maximizing on-unit outfitting. The key advantages are:

  (1) Reduced construction time due to parallel construction of structure and outfit.

  (2) Minimal impact on hull construction schedules.

  (3) Increased outfit levels.

  (4) Reduced interface of outfitting and structural activities.

  (5) Improved sequencing and control of work. Earlier application of labor and material.

  (6) Work is performed in shops which provide ideal working conditions and promote higher productivity (see Figure 5-23).

- IHI and Mitsui stated the following man-hour savings for on-unit and on-block outfitting:

  on-unit versus on-board = 70% savings
  on-block versus on-board = 30% savings

- A high degree of on-unit outfitting was observed in all shipyards performing commercial construction.
- Pictures of the DDH construction viewed in IHI Tokyo indicated limited use of on-unit outfitting and extensive on-block outfitting.
- Many examples of methods employed to further reduce the work content of outfitting can be cited. Figure 5-24 provides an illustration of the use of modular support blocks used for temporary support during assembly of a unit. These blocks represent a system of standard heights. Detail designers specify the use of particular blocks.

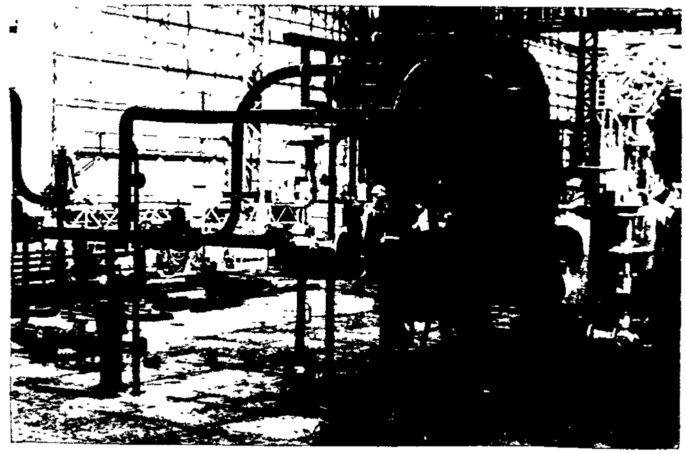

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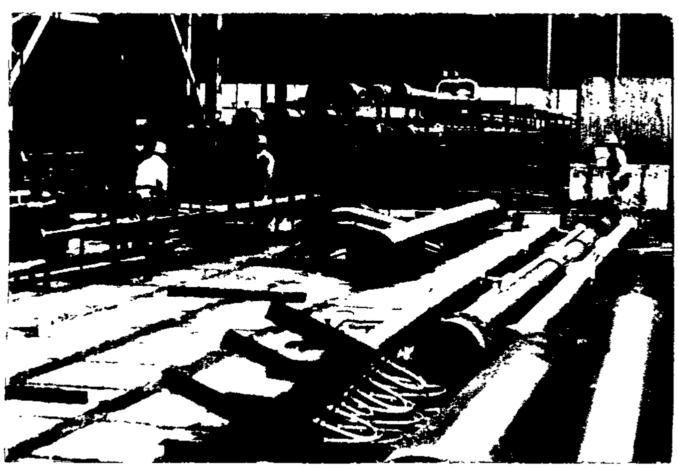
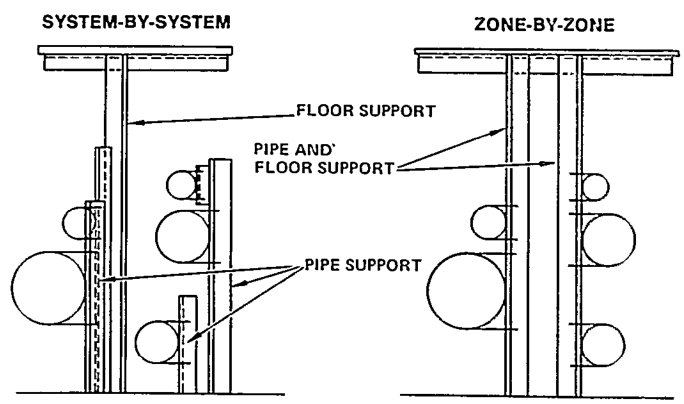
FIGURE 5-24: On-unit outfitting illustrating the use of various standardized modular support blocks.

- Figures 5-25 and 5-26 provide an illustration of the use of combined pipe supports which reduce man-hours and material.
- Outfitting on-block is the second best alternative to outfitting on-unit. As an example, significant reduction in man-hours may be obtained by on-block outfitting a containership hatch, as illustrated in Figure 5-27.



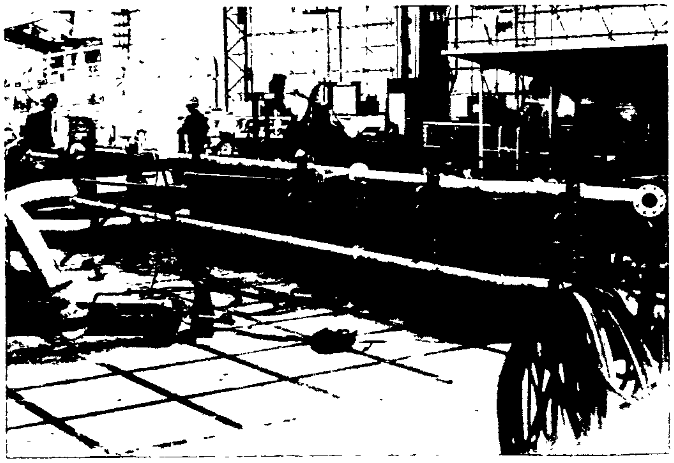
IHI, KURE

FIGURE 5-23: On-unit outfitting in progress. Work is performed in shops which provide ideal climate, lighting and access. Shop work increases the opportunity for improved safety and higher productivity. A platen area facilitates assembly of different type units.



- PIPE SUPPORT AND FLOOR SUPPORT ARE COMMON WHICH REDUCES MATERIAL COST.
- WELDING LENGTH FOR SUPPORTS IS REDUCED.
- FITTING PROCEDURE FOR EACH PIPE IS CLEARLY DETERMINED. (FROM THE LOWEST PIPE)

FIGURE 5-25: Pipe support unit assembly approach.

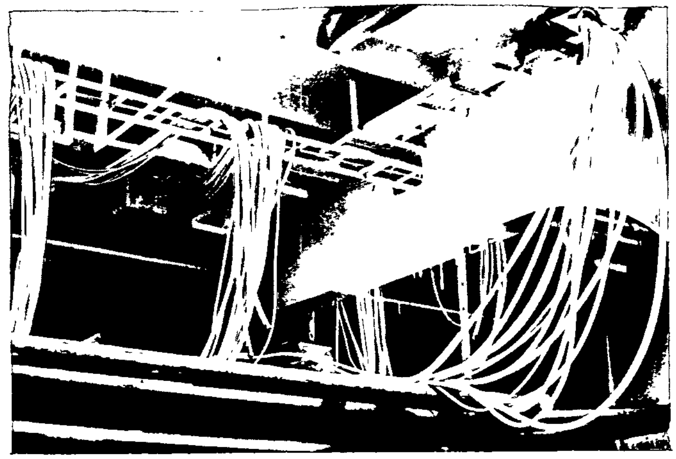


NKK, SHIMIZU

FIGURE 5-26: Combination of multiple pipes on single supports. Such pipe passages, especially when designed around main machinery, also serve to reduce the possibility of interferences.

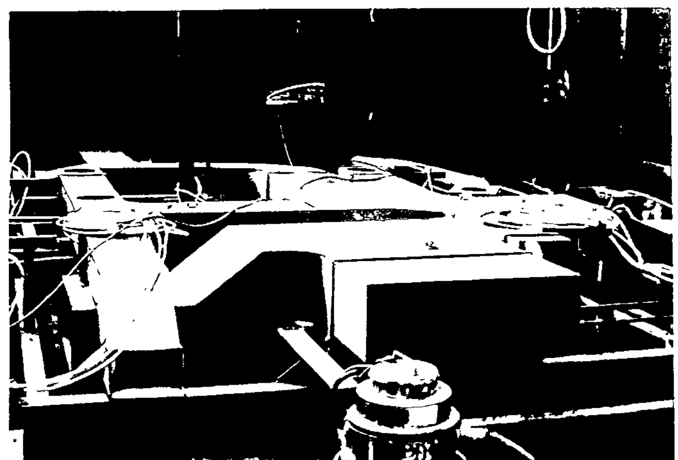
IHI, KURE

FIGURE 5-27: Ground outfitting and assembly of containership hatch coamings with hatch covers, including the completion of all dogging, seating and gasketing.



IHI, KURE

FIGURE 5-28: On-block final securing of pre-cut (palletized) cable. Cable pulling was performed down-hand before the structural block was righted.



IHI, KURE

FIGURE 5-29: On-block installation of pre-cut (palletized) cable while block is upside down.

IHI, AI01

FIGURE 5-30: Multiple pipe penetrations through decks and bulkheads preassembled with a doubler.

- Labor intensive cable pulling may also be reduced by on-block outfitting, as illustrated by Figure 5-28. Additional productivity is gained if the block is upside down during electrical outfitting, see Figure 5-29.
- Multiple pipe penetrations through decks and bulkheads may be preassembled with a doubler for ease of installation (see Figure 5-30). The doubler is also designed to serve as a structural reinforcement.
- Piping make-up pieces are normally prefabricated with two flanges tacked and unwelded. In rare cases, such as for piping running at odd angles, make-up pieces are templated aboard ship.

- In the pipe fabrication shop, work is organized by similar procedures or processes, such as bending pipe, which is the same process regardless of pipe function. This categorization of procedures is given the name Pipe Piece Family Manufacturing (PPFM) . Figure 5-31 illustrates the use of PPFM from design through palletizing.
- It is also more productive to paint these pipes and palletize them immediately following fabrication as shown in Figure 5-32, and also to perform required pressure tests in shops rather than on-board (see Figure 5-33).
- Outfit components, other than piping, are subcontracted for fabrication thus permitting shipbuilding managers to focus their attention on the assembly process. Figure 5-34 provides an illustration.
- Material control is enhanced if a single organizational unit has the responsibility to palletize both piping (fabricated within the shipyard) and other components

IHI, KURE

FIGURE 5-3.2 Use of pipe shop area for other than fabrication: 25% devoted to sorting by coating system, cleaning and painting, 25% devoted to palletizing.

MATERIAL AND TYPE		PPFM NO	NAME	REMARKS	ROUGH SKETCH FOR SHAPES
STEEL PIPES	GROUP 2 PIPES	01	STRAIGHT PIPES		
		11	AFTER-BENDING PIPES	PIPES TO BE BENT AFTER FABRICATION	
		41	PRE-BENDING PIPES	PIPES TO BE BENT BEFORE FABRICATION	
		51	FABRICATING PIPES		
		31	ASSEMBLING PIPES		
	GROUP 1 PIPES	21	PIPES TO BE SUBJECTED TO RADIOGRAPHIC TEST		
NON-FERROUS PIPES		87	NON-FERROUS PIPES	COPPER PIPES, ALUMINUM BRASS PIPES, COPPER-NICKEL PIPES, ETC.	
STEEL PIPES & NON-FERROUS PIPES	ADJUSTING PIPES	91	ADJUSTING PIPES		
CAST STEEL PIPES		71	STRAIGHT PIPES		
		73	BENDING PIPES		

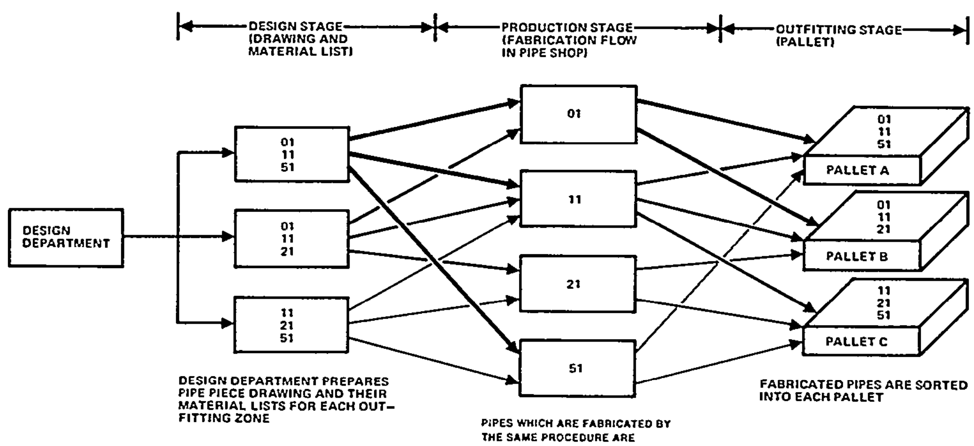


FIGURE 5-31: Pipe piece family manufacturing (PPFM).

NKK, SHIMIZU

FIGURE 5-33: Pipe pieces assembled together for pressure test in pipe fabrication shop.

MITSUI, TAMANO

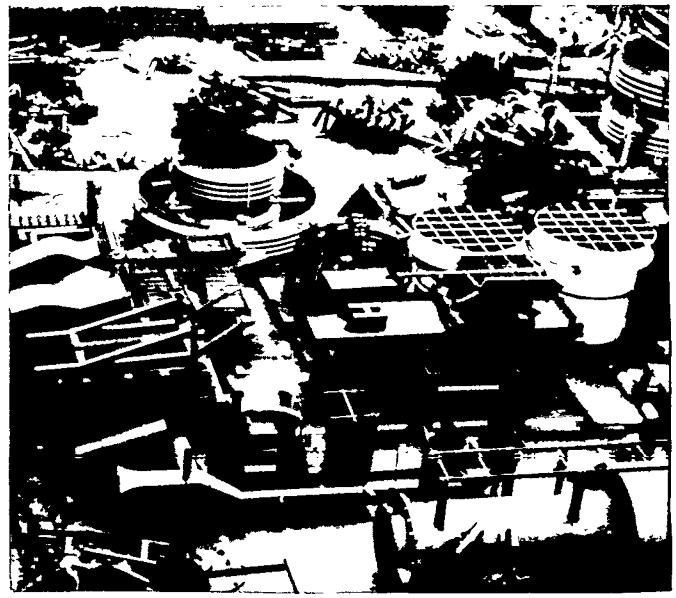
FIGURE 5-34: Subcontractor provided pipe supports which have galvanized U-bolts temporarily attached for ease of in-process material control.

(fabricated by subcontractors). This process is further simplified by control of the deliveries of subcontractor provided components (see Figure 5-35).

5.6 Dimensional Control

l Structural dimensional control was very advanced in the yards visited. Midship units were fabricated neat with no stock, and most bow and stern blocks were cut neat at assembly.

l The dimensional control approach was described as the monitoring and control of each fabrication, sub-assembly and assembly operation based upon worker and supervisory quality control inspection and documentation.



IHI, KURE

FIGURE 5-35: Views of subcontractor provided fabricated materials, delivered in lots that match specific pallets.

Dimensional control standards were stated to be based upon experience and statistical projections of cumulative errors.

This system is considered key in their low assembly and erection man hours as fitup was excellent and rework was minimal.

Stricter adherence to established schedules is achieved because the application of their dimensional control methods result in minimal rework. This is a factor of increased significance in the application of zone construction (parallel zone outfitting and hull block construction).

5.7 Steel Construction

l The block breakdown is defined very early in the contract period and is a key input for functional and detail design.

l The steel plate and shape storage yards are very small compared to U.S. practice. Steel is normally delivered only one or two days prior to fabrication.

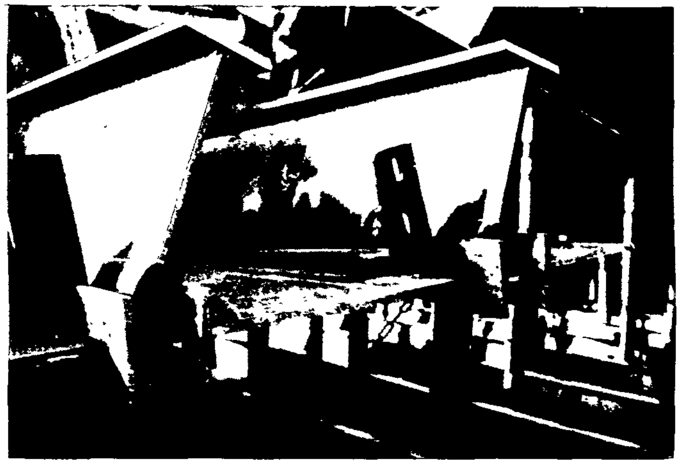
l Steel fabrication and assembly shops are large and very well laid out. The area used for steel assembly, relative to the area devoted to ship erection, is greater than in U.S. practice.

l Steel plates were typically laid out using optical projection in the electrophoto marking process (EPM). After layout, the plates were transferred to a cutting conveyor where they were cut to shape manually. Limited use of numerical control cutting machines was observed.

- Steel shapes were laid out and burned to shape manually while moving on conveyors. The burning conveyors for plates and shapes were similar to those used in the US. The use of conveyors in these applications eliminated crane and handling time.
- Limited use of plate rolls and presses was observed. Heat line bending of plates was observed in all shipyards visited except IHI Aioi [6].
- Subassembly areas were large and well laid out. The subassembly of small floors and web frames was typically accomplished on a moving conveyor or on raised pin jigs. The subassemblies for tanker web frames included staging clips, small lifting pads for use in assembly and handgrabs or ladders for use during assembly and erection.
- IHI has a preference for the "egg crate" assembly method (see Figure 5-36) because with a panel line:
    1. There are more trim and alignment problems with stiffeners.
    2. More facility is required.
    3. Their automatic fillet welders are a bottleneck.
- Directly after the flame planing or cutting of large plates to size, they were joined together and automatically welded with one side welding to form plate blankets.
- After welding of the grid assembly, it was joined to the flat plate blanket to form a complete flat panel block.
- Pin jigs were extensively used for the assembly of curved bilge and side shell units in all shipyards visited.
- All structural blocks were mechanically cleaned and painted prior to erection. Only limited capability for reblasting completed blocks was observed, for those blocks in storage waiting for erection.

NKK, SHIMIZU
FIGURE 5-36: Egg crate steel assembly mechanized jig.

- Midship blocks were fabricated neat with no stock, and most bow and stern blocks were cut neat at final assembly.
- Extensive use was made of jigs throughout the assembly and erection process. Figure 5-37 provides an illustration.



IHI, AIOI
FIGURE 5-37: Jigs used for curved panel structural assembly.

l Permanent access was designed into nontight structural members to facilitate access during assembly and erection.

l Heat line fairing [6], to correct for welding distortion, was observed at all sub-assembly and assembly stages. Figure 5-38 provides an illustration of this process on a large structural block prior to erection.

IHI, KURE
FIGURE 5-38: Heat line fairing to correct for welding distortion.

- Large capital intensive jigs or work fixtures have been developed for tanker and bulk carrier construction.

  These include the following:

  (1) At the Mitsui Chiba shipyard, the Rotas System was used for the construction of large 60 foot long by 1400 ton wing tanks. These large blocks were assembled on end, the vertical joints were welded using the electroslag process, and then the complete block was rotated mechanically for welding in various positions. After the completion of welding, the block was transferred mechanically to the edge of the dock, lowered into the dock, and transferred mechanically to the erection position.

  (2) At IHI Kure shipyard, a mechanical device for rotating large panels on end and providing mechanical staging was observed. This system was used to allow complete downhand welding of the web frame to panel connections.

  (3) At the IHI Kure and Aioi shipyards, mechanized work units have been developed to provide staging and services as well as mechanical assistance in the erection, fairing, and welding of shell, longitudinal bulkhead, and deck panels on large tanker and bulk carriers.

5.8 Welding

- The welding process is defined very early in the contract period and is a key input for functional and detail design.
- Subassembly welding was accomplished using gravity rods. The quality of gravity rod welding appeared excellent.
- Flat panel seams were welded using one side submerged arc welding. The one side welding process was used for thicknesses of 9 to 30mm (3/8 to 1¼ inch). The welding of the three-dimensional grids to the flat plate blanket was accomplished using gravity rods.
- Curved panel seams were welded using submerged arc welding against a temporary backing material. The welding of stiffeners and web frames to curved panels *was* accomplished using gravity rods.
- It appeared that all fitting was accomplished prior to releasing the blocks for welding. In some yards the assembly and welding of flat panel blocks was accomplished on a slowly moving floor conveyor.
- Erection welding was based on the maximum use of automatic and semiautomatic welding processes. Typical processes are as follows:

  1. Deck plating was welded with submerged arc using temporary backing.
  2. Vertical shell and bulkhead butts were welded using the electroslag process.
  3. Sloping *or* overhead surfaces were welded using oscillating flux-core or solid wire MIG against temporary backing.
  4. Vertical deck longitudinals were welded using the electroslag process. Deck longitudinals were flat bar to facilitate this process.
  5. Bottom shell, side shell and longitudinal bulkhead stiffeners were welded using the electroslag process for vertical surfaces and the submerged arc process for horizontal surfaces.

- Mitsui has developed and is testing *two* versions of welding robots for fully automated fillet welding. A limited amount of information is contained in reference 3.

5.9 Computer Aids

- Extensive application of computer aids to all aspects of ship design and construction was evident in all yards, especially those of IHI and Mitsui. Figure 5-39 [7] illustrates the comprehensive coverage of shipbuilding applications at IHI. Refer also to Figure 5-40 which is a list of applications in use at IHI. Figure 5-41 illustrates a similar situation for Mitsui. This situation probably applies as well to NKK [15].
- A wealth of information on various computer aids was distributed to the U.S. team. This is contained in reference 3, pages 3-17 through 3-26, 4-l through 4-7, and references 7 through 15. The salient points pertaining to development and use of computer aids are highlighted in the following paragraphs.
- The IHI aim in computerization is rationalization: computerization does not directly imply the act of using computers, but rather is a means of rationalization, by which the quality of the work involved is improved by the process of job review undertaken in applying computers. Since IHI has a significant number of computer applications in place, it has obviously realized significant productivity increases through this process.
- Both IHI and Mitsui have developed computer applications in areas where the return on investment is the greatest. The following paragraphs cite specific examples.
- Both companies have developed and are using applications in the outfitting area that consist of material control (maintenance of material lists, procurement, palletizing) and outfit schedu1ing.[12] The computeri-

[12] IHI utilizes manual scheduling for ship construction, but used computer scheduling for complex projects such as the floating paper pulp factory (approximately 400 milestones and 30,000 activities).

zation of material lists for procurement and palletizing is considered by IHI to be one of their most important applications.

- Both IHI and Mitsui have developed and are using systems for automated pipe fabrication (Mitsui Chiba and IHI Aioi). They also use computer applications for piping design and engineering which either interface to their automated pipe shops or produce fabrication instructions (pipe piece drawing and material lists) for manual or semiautomated pipe fabrication. Their systems also produce pallet information for pipes. Mitsui 'claimed a 60% reduction in man-hours for 70% of the pipe fabrication jobs by utilization of their MAPS system [10] (a system for both design and automated fabrication). A 5O% reduction in man-hours was cited in using this system for preparation of pipe piece drawings and material lists. [3]

- Computer aided structural design and production systems were in use in all yards visited. In these systems in particular, the natural growth of computer development and usage has been from the production department back through the shipyard organization into design and engineering. These systems in general exceed current AUTOKON capabilities in that part coding, nesting and definition of part of the internal ship's structure have been implemented using interactive techniques, minicomputers, and early data base management methods. [13, 7, 8, 9, 11, 14, 15] In the past (1968 through 1976) IHI developed four separate computer systems for structural design and production. Significant reductions in man-hours (12.8 man-hours/NC tape to 3.5 man-hours/NC tape) were reported by Mitsui in utilizing an interactive minicomputer based system for part coding and nesting when compared to their conventional APT like system. [9]

- The use of standards and modules was described in section 5.4. It is apparent that the use of standards with an appropriate computer system has strategic importance in increasing productivity. The following is a quote from reference 5.

  "Standards and modules show their greatest advantage when integrated with a comprehensive computer system. As the design and production process is consistently modularized, the computer can automatically output necessary drawings, material lists, N.C. tapes, purchasing and production control parameters, etc., from very limited input data. Modifications to meet owner's options are easily available by replacing the input data of applicable modules."

- IHI has implemented an advanced interactive computer aided design system (for both structure and outfitting) called SEABIRD [7, 8, 11] which utilizes an early data base management system (IMS). This

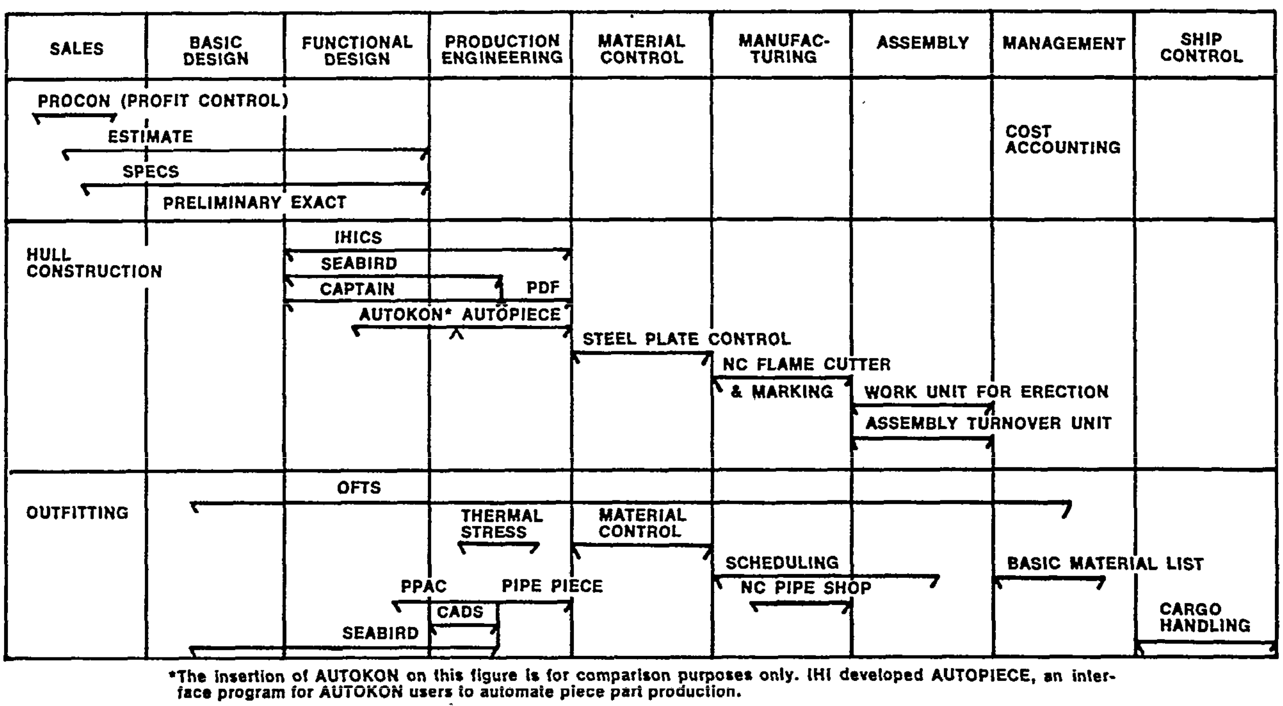


FIGURE 5-43: Shipbuilding computer applications-IHI.

	NAME OF SYSTEM	DESCRIPTION	PRESENT SITUATION (NOV. 1979) TOKYO	KURE	AIOI	DEVELOPMENT HISTORY ('69–'79)
	ZPLATE	STRUCTURAL ANALYSIS FOR PLANE STRESS (UNIVAC & IBM VERSION)	IN USE	IN USE	IN USE	ORIG-INAL; NEW VERS.
	ZUNIT	STRUCTURAL ANALYSIS FOR FRAME (UNIVAC VERSION)	IN USE	IN USE	IN USE	
	ZVIBRA	VIBRATION ANALYSIS (UNIVAC VERSION)	IN USE	IN USE	IN USE	
	SPECS	INTEGRATED SHIP CALCULATION •HYDROSTATIC PROPERTIES •STABILITY •TRIM •ETC (IBM VERSION)	IN USE	IN USE	IN USE	NEW VERSION
	TOTAL SYSTEM FOR SHIP PROPULSIVE PERFORMANCE	SHIP PROPULSIVE PERFORMANCE CALCULATION BASED ON TANK TEST, SEA TRIAL AND THEORETICAL CALCULATION FOR INITIAL DESIGN USE	IN USE (BASIC DESIGN) (UNIVAC)			
	APOLOS	APT TYPE PART PROGRAM SYSTEM FOR NC (IBM) BATCH TYPE			IN USE	
	IHICS	APPLICABLE FROM DESIGN STAGE FOR NC (HULL SYSTEM) IMS, PARTIALLY REAL TIME (IBM)	IN USE	IN USE		ORIGINAL; NEW VERSION
	CAPTAIN	APPLICABLE FROM DESIGN STAGE FOR NC (HULL SYSTEM) CADS USE (INTERACTIVE DESIGN) (UNIVAC)	STOP USAGE			
	SEABIRD	INTEGRATED DESIGN SYSTEM COVERING ALL FIELDS OF SHIP DESIGN FULL REAL TIME, INTERACTIVE DESIGN BY IBM 2250 (IBM)			STOP USAGE	
	SHELL	SHELL PLATE EXPANSION (IBM)	IN USE	IN USE	IN USE	
	LODACS	LONGITUDINAL FRAME DEVELOPMENT (IBM)	IN USE	IN USE	IN USE	
	STEEL PLATE ORDERING & CONTROL SYS	(IBM)	IN USE	IN USE	IN USE	
OUTFITTING TOTAL SYSTEM (OFTS)	PIPE PIECE DRAWING SYS	(IBM)	IN USE	IN USE	IN USE	
OUTFITTING TOTAL SYSTEM (OFTS)	WOODEN FITTING PIECE PROGRAM IN ACCOMMODATION	DEVELOPMENT OF WOODEN MATERIAL (IBM2250 USE) (IBM)			IN USE	
OUTFITTING TOTAL SYSTEM (OFTS)	ELECTRIC WIRE & CABLE WAY	DEVELOPMENT OF REQUIRED WIRE LENGTH & CABLE WAY (IBM)	IN USE	IN USE	IN USE	
OUTFITTING TOTAL SYSTEM (OFTS)	MATERIAL CONTROL SYSTEM	PALLET CONTROL (IBM)	STOP USAGE	IN USE	IN USE	
OUTFITTING TOTAL SYSTEM (OFTS)	PIPE FABRICATION SYSTEM	FOR PIPE SHOP (IBM)		IN USE	IN USE	
OUTFITTING TOTAL SYSTEM (OFTS)	OUTFITTING SCHEDULE SYSTEM	DETERMINATION OF REQUIRED DATE OF PALLET (IBM),	STOP USAGE	STOP USAGE	STOP USAGE	
OUTFITTING TOTAL SYSTEM (OFTS)	PPAC	AUTOMATIC PIPING LAYOUT (CADS USE) (IBM)		STOP USAGE		
	IR	INFORMATION RETRIEVAL OF ENGINEER-DOCUMENTS IN IHI. REAL TIME (UNIVAC)	IN USE	IN USE	IN USE	
	MICRO FILM	DOCUMENTS & DRAWINGS STORAGE & RETRIEVAL	IN USE	IN USE	IN USE	

FIGURE 5-40: Major shipbuilding software systems in use—IHI.

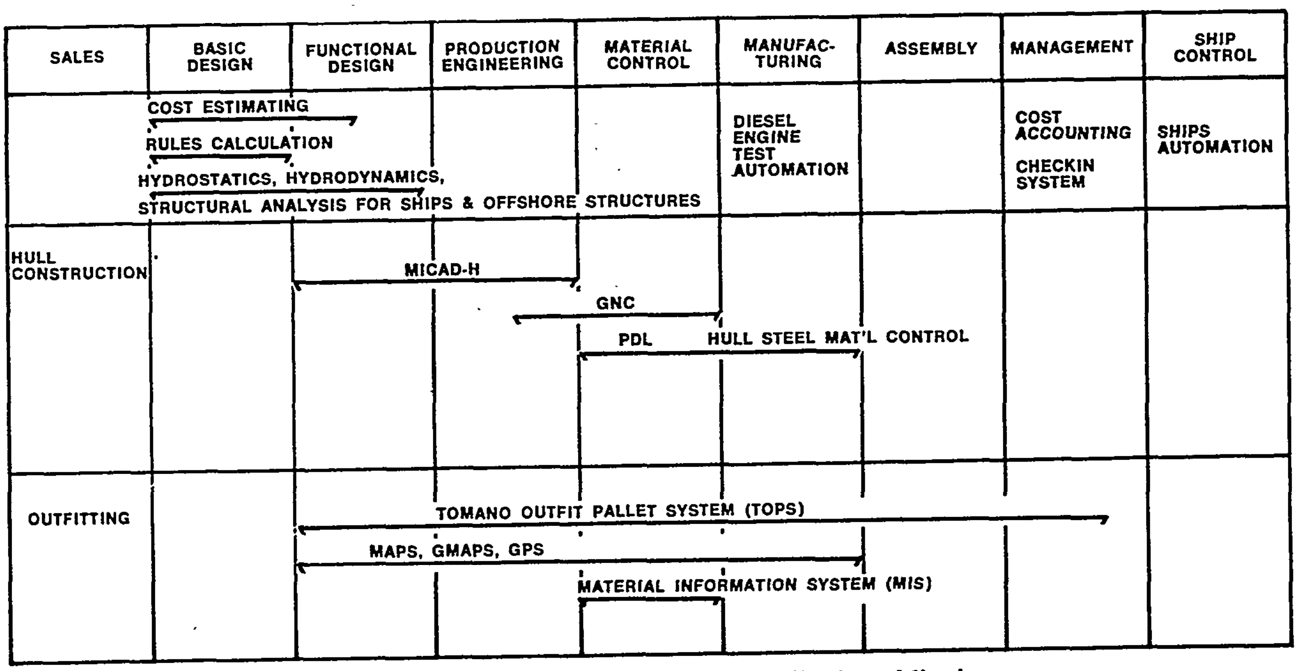


FIGURE 5-41: Shipbuilding computer applications—Mitsui.

system was used on 10 ships and resulted in a 30% savings in design cost and time. This system is no longer in use due to an excess of experienced designers[13] (in the current depressed market) and the costs required to update it to new computer technology (hardware primarily). IHI states they will use SEABIRD in the future when business improves. A significant aspect of this system is that it makes use of IHI standards and modules.

- IHI applied over 3900 man-days performing consulting services, and, developing very detailed computer system and program specifications for Italcantieri in the following areas:

  1. Hull erection system and scheduling
  2. Material control system
  3. Budget and cost control
  4. Unit outfitting methods and outfitting scheduling system.
  5. Automated pipe manufacturing and system
  6. Subassembly methods for hull construction

  As a result, over a 6 year period Italcantieri, Monfalcone progressed from three 260,000 DWT tankers per year to five per year.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on observations made in the six Japanese shipyards visited, the following items are cited as the primary reasons for their high productivity:

(1) The utilization and application of the logic and principles of zone planning and construction.

(2) The development and use of a very effective material classification scheme for definition, procurement, and control of material.

(3) The extensive use and continual development of high quality shipbuilding standards and modules.

(4) The rationalized development and use of effective cost/man-hour reducing computer aids.

While these techniques and methods are of unquestioned value in achieving productivity improvements, it is also important to note the human aspects of their application. Japanese shipbuilding middle managers are highly educated, and are rotated in various job assignments so that they acquire experience in all facets of the shipbuilding process.

6.1 Recommended Projects

A considerable amount of research and documentation of advanced methods and techniques has already been performed within the NSRP and is available with the publication of *Outfit Planning [2].*

Several U.S. shipyards (Avondale, Levingston, National Steel, Sun Shipbuilding, and Tacoma Boatbuilding) have already initiated implementation of IHI or other leading shipbuilders' methods.

Emphasis is being placed within the various panels of the Ship Production Committee to identify projects which will assist U.S. shipyards to adopt the techniques of zone planning and construction.

It is significant to note that panel SP-2 (Outfitting Aids) has already initiated the ongoing project Product-oriented Work Breakdown Structure (PWBS) in order to facilitate transition from system to zone orientation.

With these considerations in mind, and based upon the conclusions cited above, the project team has developed a series of recommended projects. Note that these recommended projects also address the nine areas cited in the MEL report [1], as those which would require minimum investment to implement. Furthermore, these recommendations are specifically oriented toward projects which will permit a more rapid adoption of the advanced technology. The following pages detail a series of proposed projects for the NSRP.

[13] Note that companies hire employees for the duration of their working life.

TITLE: Zone Planning

Background: The book, *Outfit* Planning, published in December 1979 by the NSRP introduced an advanced approach which was developed by IHI. It employs zones very productively, but impacts deleteriously to some degree on shipbuilders traditional goals to maximize steel throughput by facilitating both outfitting and painting precise zones at specified times. U.S. shipbuilders are adopting this logic and have a need to re-orient traditional hull construction and painting planners. Further, they have a need to teach outfit planners hull construction and painting options.

Objective: Expand the text of *Outfit Planning* to include hull and painting aspects of zone construction. Specifically, show that the logic for the hull block construction method and for zone outfitting and painting are identical.

Approach: In order to maintain consistency and the same level of comprehension, employ the same resource team, on a level-of-effort basis, that prepared *Outfit Planning.*

Benefits: Shipbuilders will be able to train all functionaries who impact on planning in a coordinated manner.

Cost: The overall estimated cost is $160,000.

TITLE: Zone Planning Example

Background: The book, *Outfit Planning,* published in December 1979 by the NSRP introduced an advanced outfitting approach which was developed by IHI. U.S. shipbuilders are rapidly acquiring an understanding and are formulating strategic goals. Some have already requested more detailed information to facilitate implementation.

Objective: Prepare a pamphlet for an IHI ship, which anticipates a type which would most characterize U.S. ship construction for the next decade. It is to contain examples of at least:

a. diagrammatics

b. material ordering zones

c. block breakdown

d. rough composite drawing

e. pallet list

f. composite drawing

g. work instruction drawing

h. MLS, MLP, MLC and MLF

i. etc.

Approach: Retain IHI Marine Technology, Inc., on a level-of-effort basis to prepare an English language pamphlet including explanatory material. Also, specify the level-of-effort for one subcontractor to prepare and make modifications needed for publication.

Benefits: Shipbuilders will be able to implement certain aspects of zone planning pending the end products of other more comprehensive pertinent research projects.

Cost: The estimated overall cost is $90,000 with one-half to be specified for the special graphics and modifications needed for publication.

Duration: 1 year.

TITLE: Zone Planning Educational Aids

Background: The book, *Outfit Planning,* published in December 1979 by the NSRP introduced an advanced approach which was developed by IHI. U.S. shipbuilders are already adopting the logic and have expressed a need for educational aids to assist implementation. Planning by zones necessarily means changes to traditional approaches such as those already proven by the world's most competitive shipyards.

Objective: The objective is to use the most effective techniques to describe various aspects of these new methods to lower and middle managers in U.S. shipyards.

Approach: Subdivide and prioritize the entire shipbuilding process into discrete functions. Establish the impact of the new methods on each functional category. Develop specific aids to permit understanding of the objectives and procedures already implemented by very competitive shipbuilders.

Benefits: Primarily due to the near perfect implementation of the zone approach, some shipbuilders abroad expend only one-half the time and cost per ship as compared to even the best U.S. shipyards. A general understanding will most certainly cause implementation throughout the U.S. shipbuilding industry. This would assuredly decrease these significant differentials.

Cost: The most critical training aid required would address functional and detail design. Its estimated cost is $150,000. Four additional subjects are estimated at a cost of $75,000 each.

TITLE: Handbook for Production Process Planning and Engineering

Background: The book, *Outfit Planning*, published in December 1979 by the NSRP advised U.S. shipbuilders of the relatively educated middle managers in the most competitive Japanese shipyards and their very effective development of planning and engineering of production processes. It is believed by the most successful Japanese shipbuilders, that U.S. shipbuilders are particularly deficient in not organizing and implementing in a similar manner.

Objective: Describe the pertinent logic, principles and methods of two of the most competitive Japanese shipbuilding firms. Apply special emphasis to organizations and the qualifications of incumbents.

Approach: Retain IHI Marine Technology, Inc. and Mitsui Engineering and Shipbuilding Co. on level-of-effort basis to prepare English language manuals that are well illustrated. Also, specify the level-of-effort for one subcontractor to integrate the materials, develop special graphics and make modifications as needed to produce a single manual.

Benefits: The benefits are optimized and continuously updated rationalized fabrication and assembly processes. These, when recorded as production process standards, are the bases for a shipyard's standard designs and/or provide beforehand necessary guidance for basic, functional and detail design. Further, they are an essential means for a shipyard to retain the accumulation of useful fabrication and assembly experiences.

Cost: The estimated overall cost is $280,000 with $100,000 applied to each shipbuilding firm's level-of-effort and the remainder for preparations needed for publication.

Duration: 2 years.

TITLE: Electric Cable Palletizing

Background: A few U.S. shipbuilders precut some cable to specified lengths before installation even in the first ship of a class. However, the technique is not fully exploited whereas it is a significant cost saving material control measure in general use in the Japanese shipbuilding industry. Paradoxically, because the USCG and ABS allow electric cable splices specifically to facilitate the shipbuilding process, U.S. shipbuilders have an opportunity to obtain greater such benefits than are available to shipbuilders abroad.

Objective: Describe the pertinent logic, principles and methods of two Japanese shipbuilding firms known to routinely precut cable for palletizing.

Approach: Retain Mitsui Engineering and Shipbuilding Co., and IHI Marine Technology, Inc. on level-of-effort basis to prepare English language pamphlets including explanatory materials. Also, specify the sublevel-of-effort for one subcontractor to integrate the materials, develop special graphics and make modifications as needed to produce a single pamphlet.

Benefits: The technique results in lower costs both for material procurement and handling and in vastly improved material controls and adherence to schedules.

Cost: The estimated overall cost is $140,000 with $50,000 applied to each shipbuilding firm's level-of-effort and the remainder for preparation needed for publication.

Duration: 1 year.

TITLE: U.S. Shipbuilding Standards Program-Long Term Objectives.

Background: Japanese shipbuilders have been able to achieve significant reductions in design cost and schedule duration relative to U.S. practice. A significant part of this reduction is due to their extensive design experience and the documentation of this experience in the form of standards. In that the U.S. industry has not developed this high level of design experience; and that at this time it is facing the requirement for achieving shorter design and construction periods; an expanded U.S. Shipbuilding Standards Program in the areas of functional design, detail design, and production processes is recommended. It is felt that standards developed in these areas on an industrywide basis would have greater value and acceptance than if developed only within the individual shipyards. Additionally, these standards will be a necessary input to the efficient use of advanced CAD systems that are projected to be available by the mid-1980's.

Objective: The development of a comprehensive set of U.S. shipbuilding standards in the area of functional design, detail design and production processes. These standards would be developed for the areas of hull structure, machinery, deck outfit, accommodations and electrical for the range of ship types and power plants projected for use in the 1980's and early 1990's. These standards would be used to update the MarAd shipbuilding specifications, and would be structured in a manner to facilitate their use in any advanced CAD system purchased or developed by the industry.

Approach: Purchase consulting assistance in the areas of standard development, organization, maintenance and possible purchase of existing standards from a leading Japanese shipbuilding firm (such as IHI or Mitsui) having extensive experience in these areas. Document and distribute the approach used for standards development and maintenance, and ensure the use of a standard coding system to the extent practicable. Additionally, assistance would be obtained from U.S. shipyards, design agents, owners, equipment vendors and regulatory bodies. Standards development would initially be based upon the MarAd standard designs; however, future standards development is envisioned to include the development and maintenance of standards covering the required range of ship types and power plants. The intent would be to maintain the maximum degree of similarity or standardization possible, while retaining the flexibility of individual shipyards or designers being able to easily modify the standards to suit individual service requirements.

Benefits: The proposed project would lead to increased U.S. design experience in many areas and the documentation of this experience in a form usable by shipyards, design agents, shipowners and MarAd. This would lead to a significant reduction in design cost and schedule duration, which is a key requirement to the implementation of advanced outfitting techniques such as zone outfitting and to achieving the significant savings in production cost imminent in these approaches. Additionally, documentation of design experience including feedback from all areas will assist in improving the quality of U.S. design work.

Duration: (a) Initiate the U.S. Standards Program-state objectives, develop a request for proposal, review the Japanese standards approach in the first half of 1980.

(b) Develop standards for key ship types during the 1980-1985 period (including MarAd standard designs).

(c) Expand and maintain program.

TITLE: U.S. Shipbuilding Standards Program-Functional Design Standards/Modules for Machinery Spaces.

Background: Japanese shipbuilders have been able to achieve significant reduction in design cost and schedule duration relative to U.S. practice. A significant part of this reduction is due to their experience and the documentation of this experience in the form of standards that include the area of functional design in addition to that of raw material and fittings as presently covered by the U.S. standards program. Note that the ability to speed up the design process is considered the key to the implementation of advanced outfitting techniques such as zone outfitting.

Objective: Develop with Japanese assistance in the technical and standards areas, functional design standards/modules for machinery spaces and related systems for the range of ship types and power ranges covered by the three MarAd standard designs. These would include reusable machinery space arrangements; system diagrams; definition of outfit units; pipe passage layouts; definition of system and equipment specifications; and to the extent practical, definition of alternate vendor's equipment for the main engines, generators, and key auxiliaries.

Approach: Functional design and standards development would be conducted with the assistance of consulting in the technical and standards areas from a Japanese shipbuilding firm (IHI or Mitsui) having extensive experience in these area. Additionally, assistance would be obtained from the vendors of main propulsion engines and auxiliary equipment. Functional design including arrangements, system diagrams, etc., would be developed for the three MarAd standard designs based upon two main engine vendors. The intent would be to maintain the maximum similiarity or standardization possible for this range of applications and power requirements, while retaining the flexibility of individual shipyards or designers being able to easily modify the standards to suit individual service requirements.

Benefits: The proposed project would lead to increased U.S. design experience in the area of machinery spaces and the documentation of this experience in a form usable by shipyards, design agents, shipowners and MarAd. This would in turn lead to a significant reduction in design cost and schedule duration, which is a key requirement to the implementation of advanced outfitting techniques such as zone outfitting and to achieving the significant savings in production cost imminent in these approaches.

Cost: To be developed.

Duration: 12 months-mid-1980 to mid-1981 depending upon funding.

TITLE: Construction Services

Background: For many years, U.S. shipyards have been plagued by a "helter-skelter" approach in supplying construction services to work areas for ship construction. Poor construction service practice results in poor housekeeping typified by cluttered decks and access passageways. These invite poor working conditions with resultant waste of man-hours and potential safety problems.

Objective: Develop a manual. for distribution to shipyards, which would describe and illustrate various methods by which construction services can be installed to conveniently supply all the needed services to shops and ships in a preplanned manner.

Approach: The developer of the manual should study various U.S. shipyards and selected foreign shipyards to determine present practices. Candidate areas for investigation are as follows:

1. Scaffolding is always a problem, particularly when needed in such high and hazardous places as the underside of the upper deck in large tankers and/or bulk cargo ships. Presently the scaffold builder is faced with a heel-handing operation to both build and remove such scaffolding. A possible solution is to have engineering, during development of structural drawings, design and detail special scaffolding brackets, etc., which could be installed during assembly of a hull block. Hopefully these would be approved by the owner of the vessel to permit welded clips, etc., to remain on the structure. This would make the scaffold builder's job safer in both installation and removal operations.

2. Temporary lighting, compressed air service, water for firefighting and other uses, gases used for cutting and welding, temporary phone service, etc., for on-board use. All of these services have posed big problems. Normally they are run from the ground and over the side of the vessel at the most convenient place for a worker to use at a given time. Many of these service lines remain in place and tend to accumulate into a mass of cables and hoses, mostly underfoot and down ladderways. A possible solution for on-board use, is to have a series of portable archways installed on the topmost deck of the vessel with all of the above services suspended from the top of the arch high enough above the deck to permit passage below. Standard length pipe sections (flanged) could be developed and manifolds for each system could be mounted on the archways at convenient spacing. Hoses could be used to connect systems to towers at the side of the ship which would carry service lines from distribution systems on the ground.

3. Improved material handling methods for all types of material and equipment such as various types and sizes of pallets, types of vehicles used to handle and transport and methods to lift aboard ship.

4. Welding power sources and welding power distribution systems.

5. Temporary ventilation systems for confined spaces.

6. Rigging methods and equipment to help workers handle and install all manner of equipment and material in both shops and on-board.

7. Access methods to aid in transporting workers from ground level to on-board areas, both interior and exterior. This item should also include a planned arrangement of temporary openings in ship structure for both horizontal and vertical access for workers and construction service lines.

The above list is not to be considered complete and the developer of the manual should work with shipbuilders to assure that all possible areas of construction service problems are included in this survey.

Benefits: If properly approached and accomplished, benefits would include:

1) Improved safety (dramatically)

2) Better working conditions that would produce:
   - more efficient work environment
   - reduced man-hours
   - shorter building schedules

Cost: The estimated cost is $120,000.

References: "Project Safe Yard" Long Beach Naval Shipyard.

Duration: Estimated duration is 1.5 years after award of contract.

TITLE: Jigs, Fixtures and Special Tools

Background: Observations of fabrication, assembly and installation operations at Japanese shipyards reveal many jigs and fixtures are employed to assist in joining various parts and assemblies. Many of these special tools could be readily adopted by U.S. shipyards to assist tradesmen in numerous production operations.

Objective: Develop a well illustrated manual which describes the use of jigs, fixtures and special tools.

Approach: The researcher should canvass shipyards, both foreign and domestic, for any jigs, fixtures or special tools now in use. Review equipment available from specialty-tool manufacturers who may have many tools already available (an example is the Ener-Pac Co. which markets a modified jack clamp using a small portable hydraulic jacking device for aligning structures for joining).

Benefits: The use of special jigs, fixtures and tools can yield:
- Safer and better working conditions
- Reduced manhours and cost
- More efficient use of material and services

Cost: The estimated cost is $100,000.

Duration: Estimated duration is 1.5 years after award of contract.

IMPLEMENTING IHI TECHNOLOGY AT AVONDALE

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ABSTRACT

This is a presentation of basic advantages, successes, and problems experienced with the introduction of IHI technology into an American shipyard. Fundamental and historical patterns that must change in order for this technology to be completely successful are discussed.

IMPLEMENTING IHI TECHNOLOGY AT AVONDALE

IN MAY, 1979, A FIRM DECISION WAS MADE BY MANAGEMENT AT AVONDALE SHIPYARDS TO ENGAGE THE SERVICES OF IHI MARINE TECHNOLOGY, INC. FOR A COMPREHENSIVE SURVEY OF OUR ENGINEERING AND PRODUCTION METHODS.

THE SURVEY COMMENCED ON AUGUST 29, 1979 AND COMPLETED ON OCTOBER 2. THE SURVEY WAS CONDUCTED BY SEVEN (7) MEMBERS FROM IHI.

A PRELIMINARY REPORT WAS GIVEN TO SHIPYARD MANAGEMENT ON OCTOBER 1, AND ON THE BASIS OF THE PRELIMINARY FINDINGS, IT WAS DECIDED THAT FURTHER TECHNOLOGY EXCHANGE WOULD BE BENEFICIAL IN ORDER TO:

(1) IMPROVE CONTRACT DELIVERY TIME,

(2) SHORTEN HULL CONSTRUCTION PERIODS,

(3)' REDUCE ENGINEERING AND LABOR COSTS.

A PROPOSAL FOR SERVICES FROM IHI MARINE TECHNOLOGY, INC. WAS THEN REQUESTED. THE PROPOSAL WAS SENT TO AVONDALE IN NOVEMBER 1979 AND CONSISTED OF THE FOLLOWING:

(1) ASSISTANCE IN ACCURACY CONTROL FOR A PERIOD OF THREE (3) MONTHS USING ONE (1) ENGINEER,

(2) ASSISTANCE IN PRODUCTION HULL PLANNING AND PRODUCTION OUTFITTING PLANNING FOR A PERIOD OF SIX (6) MONTHS WITH TWO (2) ENGINEERS.

(3) ASSISTANCE ON COMPUTER APPLICATION FOR A PERIOD OF TWELVE (12) MONTHS WITH ONE (1) ENGINEER.

IT WAS DETERMINED THAT THE STUDY AND EXCHANGE EFFORT WOULD BE DEVOTED TO A MAXIMUM OF TWO (2) CONTRACTS:

(1) A THREE (3) VESSEL CONTRACT FOR CONTAINER SHIPS.

(2) A SINGLE VESSEL CONTRACT FOR A HOPPER DREDGE.

SOME PROBLEMS WE FOUND, FOR EXAMPLE, WERE VERY BASIC BUT ARE, OF COURSE, HISTORICALLY WELL KNOWN TO AMERICAN SHIPBUILDING. AS AN EXAMPLE, THE LENGTH OF DESIGN TIME! COMPARED TO TOTAL CONTRACT TIME, DESIGN TIME IS EXCESSIVE.

WHEN THIS IS RELATED TO IHI DESIGN VERSUS CONTRACT TIME, IT BECOMES EVIDENT THAT THE DIFFERENCES REPRESENT A SERIOUS CHALLENGE TO AMERICAN SHIPBUILDERS.

EACH AMERICAN SHIP OR VESSEL IS MORE OR LESS A CUSTOM BUILT ENTITY. DESIGN CHANGES OCCUR VERY FREQUENTLY AFTER CONTRACT DUE TO REQUIREMENTS FROM OWNERS AND REGULATORY BODIES. ANOTHER BASIC PROBLEM IS RESOLUTION OF VENDOR INFORMATION AND EVALUATION OF TECHNICAL DATA ON GUIDANCE AND CONTRACT DRAWINGS FROM SHIP OWNERS, CONSULTANTS AND NAVAL ARCHITECTS. IT OFTEN IS UNCLEAR AND REQUIRES MUCH IN MAIL TIME TO CLARIFY.

THE IHI RECOMMENDED PROCEDURES DEVELOPED FOR AVONDALE SHIPYARDS WORK TOWARD A FINAL DESIGN DURATION OF EIGHT (8) MONTHS FOR FUTURE SHIPS. THIS REQUIRES MUCH MORE UP FRONT EFFORT PRIOR TO CONTRACT SIGNING. IT ALSO MEANS A TIGHTER, MORE EXPENSIVE AND LENGTHIER COOPERATIVE EFFORT BETWEEN PRODUCTION PLANNING, MARKETING AND SHIP OWNERS PRIOR TO BIDDING OR NEGOTIATING THE CONTRACT.

IN ADDITION TO THE EARLIER ON EFFORT, MANY STRUCTURAL CONNECTIONS AND BRACKETS ARE NOW PLANNED TO BE MADE STANDARD AND PRE-APPROVED BY CLASSIFICATION SOCIETIES, SO THAT THEIR USE WILL ELIMINATE THE LENGTHY TIME APPROVAL NECESSARY IN THEIR INCORPORATION ON FUTURE CONTRACTS.

PROBLEMS ALSO DIFFICULT TO RESOLVE ARE PROCURED ITEMS; SUCH AS **MACHINERY**, MISC. EQUIPMENT AND CRITICAL MATERIALS.

IT ACCOMPLISHES LITTLE TO SHORTEN DESIGN AND HULL CONSTRUCTION TIME IF EQUIPMENT AND MATERIAL DELIVERIES ARE LATE OR UNDEPENDABLE.

TO CUT OPENINGS IN THE COMPLETED HULL FOR LATE EQUIPMENT INSTALLATION, WHEN USING THE IHI TECHNOLOGY, ONLY MEANS THE JOB IS COMPLETELY OUT OF PHASE.

AN EFFORT IN PROGRESS TO ALLEVIATE THIS PROBLEM IS THE ADOPTION OF A MATERIAL AND MANUFACTURING STANDARDS CATALOG AND HAVING THESE STANDARDS APPROVED BEFORE OR AT CONTRACT SIGNING BY OWNER AND CLASSIFICATION SOCIETIES.

IT IS ESSENTIAL IN DEVELOPING MACHINERY AND EQUIPMENT STANDARDS TO ALSO MARE VENDORS STANDARDS PROFITABLE TO THE VENDOR BY PROVIDING A LIMIT TO THE VARIETY OF TYPES, SIZES AND MATERIALS USED. THE TIME FRAME FOR PROCUREMENT CAN THUS BE SHORTENED. STANDARDS DO NOT REQUIRE EXTENSIVE COMMUNICATIONS WITH VENDORS AND OWNERS TO FINALIZE A SPECIFICATION. ONE GOOD REASON FOR RECOMMENDING THE USE OF STANDARDS IS A PASS ON BENEFIT SHARED BY THE SHIPOWNER AND A FASTER DELIVERY TIME FOR HIS VESSEL.

SPECIFIC EFFORTS UNDER WAY, NOW, AT AVONDALE, ARE AS FOLLOWS:

(1) WE INTEND TO CONSISTENTLY PURCHASE SIMILAR EQUIPMENT FROM THE SAME VENDOR INSOFAR AS POSSIBLE AND THEREBY HOPE TO GAIN THEIR CONFIDENCE IN US AS A FUTURE CUSTOMER AND AN INCREASED INTEREST ON THE PART OF THE VENDOR'S MANAGEMENT.

(2) WE ARE DEFINING THE VENDOR REQUIREMENT FOR EQUIPMENT IN THE ADVANCED PROGRAMS GROUP NOW IN SUFFICIENT PRE-BID DETAIL TO ALLOW THE PURCHASING DEPARTMENT TO PLACE ORDERS IMMEDIATELY UPON RECEIPT OF A CONTRACT.

THE STUDY OF DRAWINGS REVEALED PROBLEMS THAT MANY SHIPYARDS HAVE HAD OVER THE YEARS.

WORKING DRAWINGS HAVE HISTORICALLY BEEN OF A LARGE SIZE AND FILLED WITH A MULTITUDE OF INFORMATION TO SATISFY EVERYONE. THIS HAS LED TO A COMPLEX AND SOMETIMES HARD TO DECIPHER DOCUMENT THAT BECOMES VERY DIRTY AND TORN DURING CONSTRUCTION USE.

UNDER RECOMMENDATIONS BY IHI, TODAY THIS SITUATION IS CHANGING. QUOTING WORDS FROM MR. OGAWA OF IHI (quote) "AFTER DIGITAL COMPUTER SYSTEMS ARE INTRODUCED IN THIS FIELD, THE WORKING DRAWINGS WILL BE CHANGED TO BE DRAWN LESS GEOMETRICALLY AND MORE NUMERICALLY. COMPUTER PROGRAMS ACCEPT ONLY NUMERICAL DATA, AND SINCE HULL STRUCTURES, MACHINERY, PIPES AND OTHER ITEMS ARE INDICATED BY NUMERICAL SIZES, THE NECESSITY FOR GEOMETRICAL ACCURACY IS COMPARATIVELY REDUCED.

MORE MANHOURS ARE REQUIRED TO PRODUCE GEOMETRICALLY ACCURATE. DRAWINGS, BECAUSE ON GEOMETRICAL DRAWINGS ALL AREAS MUST BE ACCURATE, WHILE ON NUMERICAL DRAWINGS ONLY MAJOR POINTS MUST BE ACCURATE." (unquote)

WORKING DRAWINGS IN THE NEAR TERM WILL BE OF A CONVENIENT SIZE AT AVONDALE SINCE THEY WILL BE FOR SHIPYARD USE ONLY. THEY WILL BE ISSUED ON A "NEED TO KNOW" BASIS SIZED ACCORDING TO PACKAGE, UNIT SUB ZONE OR ZONE. BASICALLY, ONE WORKING DRAWING WILL CORRESPOND TO ONE GROUP OF JOBS CALLED (A PALLET). IT WILL INCLUDE ALL MATERIALS -HANDLED AT ONE WORKING STAGE, IN ONE ZONE AND AT ONE TIME.

DRAWINGS WILL BE SIMPLIFIED, USING WHAT IS TERMED SYMBOLIC LOGIC. SYMBOLIC LOGIC IS USED TO REPLACE AND CLEAR THE DRAWING OF MISCELLANEOUS DETAILS. THESE DETAILS HAVING BEEN ESTABLISHED AS STANDARDS THROUGHOUT THE ENTIRE SHIPYARD, AND REPLACED BY SYMBOLS.

BY EARLY NEXT YEAR, AVONDALE WILL HAVE IN THE FIELD ALL DRAWINGS FOR THE HULL PRE-FAB, SUB-ASSEMBLY, ASSEMBLY AND ERECTION OF THE A.P.L. CONTAINER SHIP CONTRACT. THIS GROUP OF DRAWINGS WILL BE CALLED THE UNIT CONTROL MANUAL:

THESE DRAWINGS WILL BE BY PROCESS STAGE OF CONSTRUCTION AND NO DRAWING WILL MEASURE OVER 8½" x 17", YET IT WILL HAVE ALL THE INFORMATION NECESSARY FOR CONSTRUCTION. THE SAME IS BEING DEVELOPED FOR PIPING, PACKAGE UNITS, ZONE AND SUB-ZONE ON-BOARD OUTFITTING.

ONE OF THE FIRST STUDIES TO BE RECOMMENDED AND IMPLEMENTED WAS ACCURACY CONTROL.

TO THIS END, A QUALIFIED AVONDALE ENGINEER WAS PLACED IN CHARGE OF AN ACCURACY CONTROL GROUP. IN MARCH 1980, WITH THIS GROUP AND WITH IHI ENGINEERS, A PILOT PROGRAM WAS RUN ON A NUMBER OF UNITS SELECTED FROM A SINGLE SHIP IN CONSTRUCTION. GROUND RULES WERE ESTABLISHED AND TAUGHT TO VARIOUS FRONT LINE SUPERVISORS.

SEVERAL COMPLETED ASSEMBLIES WERE DIMENSIONED BY IHI METHODS AND THE INACCURACIES WERE LOCATED AND CORRECTED. SINCE APRIL 1980, MOST EFFORTS HAVE GONE INTO THE PRE-FABRICATION AND PANEL LINE SHOP. ACCURACY CONTROL SHEETS 'WERE SET UP AS A STANDARD FEEDBACK AND INFORMATION FORM. PIECES WERE CHECKED ON A PERCENTAGE BASIS, THAT IS; IF 20 OUT OF 20 PIECES WERE FOUND TO BE INACCURATE, THEN 100% OF THESE PIECES WERE CHECKED UNTIL THE PERCENTAGES DROPPED. IF THE INACCURACIES DROPPED OR OCCURRED IL? ONLY 1 OUT OF 20 PIECES, THEN ONLY 5% OF THESE WERE INSPECTED.

THIS GROUP NOW OPERATES ON A CONTINUOUS BASIS IN THE SHOP WITH MINIMUM SUPERVISION FROM IHI.

SINCE INITIATING ACCURACY CONTROL IN THE PRE-FABRICATION AND PLATE SHOP, THE ACCURACY HAS IMPROVED DRAMATICALLY, AND THE GROUP IS NOW READY TO EXPAND INTO OTHER AREAS OF FABRICATION AND ASSEMBLY AS PROCESS LANES ARE DEVELOPED.

PHYSICAL SHIP CONSTRUCTION STARTS WITH THE STEEL PRE-FABRICATION, SUB-ASSEMBLIES, UNIT ASSEMBLY AND ERECTION OF THE HULL. GROSS HULL CONSTRUCTION IS ROUGHLY BROKEN DOWN INTO THE FOLLOWING PERCENTAGES.

IN THIS REGARD, AVONDALE AND IHI ARE NOW COMPLETING A STUDY AIMED AT RE-ORGANIZING THE VARIOUS YARD PLATENS AND STEEL WORK CENTERS INTO MANUFACTURING PROCESS LANES CAPABLE OF ASSEMBLING 8000 TONS OF STEEL PER MONTH. PROCESS LANE PARAMETERS FOR TONNAGE FLOW IS BEING CALCULATED BY AREA AS SHOWN IN THESE LAYOUTS: FIRST, BY SHARE CATEGORIES; 4 SECOND, 5 BY THE WEIGHTED PERCENTAGE OF EACH CATEGORY BY SHAPE PROJECTED ON A DESIRED THROUGH PUT OF 8000 TONS PER MONTH; THIRD, 6 BY A RELATIONSHIP BETWEEN THE TOTAL UNIT WEIGHT ASSEMBLED AND THE AREA FOR EACH BAY USING FOR COMPARISON A THROUGH PUT OF 7,000 TONS A MONTH EXPERIENCED AT IHI. PRODUCTION AREA FLOW RATES AT IHI ARE TWICE AMERICAN RATES. TARING INTO ACCOUNT GREATER WORKER EXPERIENCE AND THE FACT THAT MORE AREAS IN JAPAN ARE UNDER ROOF, 7 THE FOLLOWING CALCULATION IS PROJECTED FOR AVONDALE. A TONNAGE FLOW OF 8,000 TONS PER MONTH FOR OUR YARD IS ESTIMATED TO NEED AN AREA BREAKDOWN AS SHOWN, WITH THE FIGURES IN PARENTHESES SHOWING IHI'S RATIO. USING THIS BREAKDOWN AS A GUIDE, THE EXISTING AVONDALE PLATENS SEEM MORE THAN ADEQUATE FOR THE INCREASE IN TONNAGE FLOW. THIS MEANS, OF COURSE, LITTLE OR NO CAPITAL INVESTMENT REQUIRED FOR ADDITIONAL AREA. SOME CAPITAL WOULD BE REQUIRED, OF COURSE, FOR CONVEYORS OR OTHER DESIRED MECHANICAL AIDS FOUND TO BE NECESSARY. THIS WILL VARY SOMEWHAT WITH THE TYPE OF VESSEL AND TYPE OF CONSTRUCTION USED.

THE STUDY IS SCHEDULED TO COMPLETE BY MIDDLE OCTOBER AND IS CONSIDERED TO BE A MOST IMPORTANT AND VITAL STEP TO NOT ONLY REDUCE HULL COSTS BUT IN ESTABLISHING DESIGNATED AREAS AND LANES FOR CONTROL OF MATERIAL AND DETERMINING PRE-OUTFITTING STAGES. THE IMPLEMENTATION OF THIS STUDY IS EXPECTED TO DEVELOP OVER A PERIOD OF 8 TO 12 MONTHS.

PIPING INSTALLATIONS IN SHIPBUILDING REPRESENT A VERY EXPENSIVE EFFORT IN MATERIAL AND LABOR. PIPING IS THE SECOND MOST COSTLY ITEM IN SHIP CONSTRUCTION AT AVONDALE.

AS A MATTER OF PRACTICE, UP UNTIL RECENTLY, THE ENGINEERING DEPARTMENT AT OUR YARD HAD LIMITED ITS PIPING DETAIL SKETCHES OF PIPE PISCES TO ONLY THOSE SIZES OF PIPE 2" AND ABOVE. THIS MADE THE PRODUCTION PIPE DEPARTMENT RESPONSIBLE FOR FIELD RUNNING PIPING UNDER 2", GENERATING A TENDENCY TO CREATE INTERFERENCE PROBLEMS. MUCH DECISION MAKING BY FRONT LINE SUPERVISORS AND MIDDLE MANAGEMENT FOREMEN ALSO RESULTS IN COSTLY MARKING, CUTTING, BENDING AND FABRICATION ON THE JOB SITE INSTEAD OF CONVENIENTLY IN THE SHOP.

ON RESEARCHING VARIOUS TYPES OF VESSELS, 8 IT WAS FOUND THAT PIPE PIECES BELOW 2" IN SIZE REPRESENT APPROXIMATELY 50% OF THE TOTAL AMOUNT OF PIPE PIECES IN A VESSEL. AN 1,800 UNIT CONTAINER SHIP, FOR EXAMPLE, BUILT AT IHI HAS A TOTAL OF 13,047 FABRICATED PIPE PIECES, APPROXIMATELY 6,950 OF WHICH ARE UNDER 2".

AS YOU CAN SEE, THE AMOUNT OF PIPE PIECES BELOW 2" CAN BE A CONSIDERABLE NUMBER. ON THIS BASIS, IT HAS BEEN DECIDED TO ENGINEER AND FABRICATE MOST PIPE PIECES DOWN TO AND INCLUDING ½" SIZES. THESE PIPE PIECES DRAWN BY "CADAM" WILL' APPEAR NOT ONLY AS SKETCHES, BUT SKETCHES THAT INCLUDE MATERIAL SPECIFICATIONS, JOB ORDER, PALLET NUMBERS, PLANNING ROUTINES, ROUTING AND COATING

OR FINAL TREATMENT SPECIFICATIONS. THE PERTINENT INFORMATION WILL BE TRANSLATED TO THE SHOP MANAGEMENT CODES AND STORED IN THE COPIES SHOP MANAGEMENT SYSTEM FOR SEMI-AUTOMATED PIPE SHOP MANUFACTURING. PIPING, AS A RESULT OF IHI ZONE OUTFITTING TECHNIQUES, IS NO LONGER FABRICATED IN OUR YARD BY ENTIRE SYSTEMS BUT BY PALLET, PRE-OUTFIT UNIT AND ZONE SCHEDULES.

THIS WILL REDUCE CONSIDERABLY THE AMOUNT OF FABRICATED PIPE PIECES THAT GENERALLY TAKE UP INACTIVE STORAGE SPACE. IT ALSO LENDS ITSELF TO A MUCH MORE EFFICIENT SHOP MANAGEMENT SYSTEM WITH PIPE PIECES BEING PALLETIZED FOR DESIGNATED FINAL TREATMENT OF PRE-OUTFIT AND ZONE LOCATION.

MUCH HAS BEEN ACCOMPLISHED AT THIS POINT IN THE MANUFACTURING OF PACKAGE UNITS AND ON UNIT OUTFITTING AT AVONDALE. ON THE A.P.L. CONTAINER SHIPS, FOR INSTANCE, A TOTAL OF FORTY-ONE (41) MACHINERY PACKAGE UNITS HAVE BEEN DEVELOPED. THIS DOES NOT INCLUDE THOSE ENTIRE UNITS THAT ARE VIRTUALLY PACKAGES IN THEMSELVES.

THE DRAWINGS PRODUCED BY ENGINEERING IN THE DESIGN OF THESE PACKAGE COMPONENTS ARE A COMPOSITE OF THE COMBINED IDEAS OF ENGINEERING, PRODUCTION PLANNING AND THE PRODUCTION FIELD. THUS THEY REPRESENT A CONSENSUS OF THE MOST DESIRABLE CONSTRUCTION METHODS.

WEEKLY MEETINGS TAKE PLACE ON EACH JOB WITH EACH DEPARTMENT REPRESENTED BY A WORKING MEMBER. DRAWINGS ARE DISCUSSED EARLY IN THEIR DEVELOPMENT AND, IF SEEN NECESSARY, ARE CHANGED TO THE OPTIMUM CONSTRUCTION METHODS. PIPING IS REROUTED IF REQUIRED. PRODUCTION IDEAS ARE INCORPORATED INTO WORKING DRAWINGS 'WHENEVER POSSIBLE.

THESE MEETING ALSO SERVE AS THE FEEDBACK FORUM FROM THE FIELD FOR DRAWING CORRECTIONS AND MODIFICATIONS.

PRE-OUTFITTING ON UNIT AND ON BOARD IS PROBABLY THE MOST RE-COGNIZED TECHNIQUE AT THIS PARTICULAR TIME IN OUR YARD. THE REASON FOR THIS IS THAT IT IS THE MOST VISIBLE AND MOST EASILY UNDERSTOOD BY THE WORK FORCE.

THE BENEFITS AND ADVANTAGES OF UNIT AND ZONE OUTFITTING ARE MOST APPARENT TO THE EMPLOYEE AND FRONT LINE SUPERVISOR PERFORMING THE WORK. THE FACT THAT HE IS ABLE TO PRE-OUTFIT IN FRESH AIR AND GOOD LIGHTING, THOSE ITEMS HE PREVIOUSLY HAD TO DO IN CLOSED TANKS AND POOR VISIBILITY, SHOW HIM INSTANT PRACTICAL ADVANTAGES FOR ADOPTING THE SYSTEM.

THE IMPROVED SAFETY CONDITIONS AND LESS OF A COMPETITIVE STRUGGLE FOR FACILITIES SHOW HIM PERSONAL ADVANTAGES FOR ITS ADOPTION.

AS IN ALL MANUFACTURING, SOME PARAMETERS MUST BE USED TO GAGE THE EFFECTIVENESS OF THE METHODOLOGY BEING USED.

IN THE CASE OF PRE-OUTFIT PLANNING AND ZONE OUTFITTING, THERE ARE SEVERAL MEANS TO EVALUATE PERFORMANCE. ONE IS TONNAGE OF PRE-OUTFIT ITEMS INSTALLED PRIOR TO REEL LAYING,. ERECTION AND LAUNCH. THIS METHOD IS POPULAR AT IHI.

THE METHOD TENTATIVELY BEING CONSIDERED BY AVONDALE IS TOTAL MANHOURS OF OUTFITTING PRIOR TO REEL AND TOTAL MANHOURS PRIOR TO LAUNCH VERSUS TOTAL MANHOURS OF OUTFITTING AFTER LAUNCH TO DELIVERY. THIS WILL COMPARE TO A PAST PERFORMANCE BASE TAKEN FROM APPROXIMATELY *TWENTY (20)* VESSELS. THE MEASURED PERFORMANCE WILL BE ARRIVED AT AS A PERCENTAGE GROWTH OF OUTFITTING BEING ACCOMPLISHED PRIOR TO KEEL AND LAUNCH. THIS APPROACH OF GAGING PERFORMANCE PROGRESS WILL BE USED UNTIL A MORE SOPHISTICATED METHOD CAN BE ESTABLISHED FROM HISTORICAL DATA ON A WEIGHT BASIS.

IN ALL OF THIS, IT IS MOST IMPORTANT TO SERIOUSLY CONSIDER SCHEDULING. SCHEDULING IS THE DISCIPLINE THAT STITCHES EACH OPERATION TOGETHER IN ITS PROPER ORDER. EACH DEPARTMENT, FROM ADVANCED PROGRAMS, THRU ENGINEERING, DOWN TO PRODUCTION, HAS SCHEDULE RESPONSIBILITY. THESE RESPONSIBILITIES FOLLOW PRECISE TIME PATTERNS OF WHAT IS TO BE ACCOMPLISHED WITHIN DESIGNATED TIMEFRAME. 9

SHOWN HERE IS AN EXAMPLE OF TIME SCHEDULING AT AVONDALE BY DEPARTMENT AS IT RELATES TO HULL PROGRESS FROM MARKETING THRU DESIGN AND ENGINEERING TO MOLD LOFT. RESPONSIBILITIES OF THIS CHART ARE ONLY BRIEFLY DEFINED BECAUSE OF CHART SIZE.

CERTAIN INFORMATION, AS YOU CAN SEE, MUST BE DEVELOPED AND CONSOLIDATED FOR ISSUING IN TIME FOR THE PRE-PLANNED MEETING DATES INDICATED BY "CONTRACT", "K", "B" AND SO FORTH. 10

FROM THIS IS DEVELOPED A "TREE STRUCTURE OF SCHEDULES" THAT INCLUDE FABRICATION, OUTFITTING AND TESTING. THIS IN TURN BREAKS DOWN ALL WORK EFFORT INTO DETAIL SCHEDULES FOR EXECUTION. PARTICIPATION EFFORT IN MAKING THESE SCHEDULES ORIGINATES ALL THE WAY FROM FRONT LINE FOREMEN AND MECHANICS TO MIDDLE AND UPPER MANAGEMENT.

IT IS EXTREMELY IMPORTANT THAT SCHEDULES BE:

(A) REALISTIC - THAT IS TO SAY SAFELY WITHIN THE FACILITY AND PERSONNEL MAXIMUM LOADING, CAPABILITY.

(B) RECOGNIZED - THIS MEANS THEY ARE OFFICIAL DOCUMENTS OF TOP MANAGEMENT AND CAN ONLY BE CHANGED BY TOP AUTHORITY.

(C) RESOLUTE - THIS INDICATES THEY ARE REGARDED BY ALL EMPLOYEES AS STEADY AND DETERMINED WORK GUIDES.

AS OF SEPTEMBER 15, 1980, THERE ARE MANY MAJOR EFFORTS BEING

STUDIED AND CONSIDERED FOR IMPLEMENTING AT AVONDALE SHIPYARDS.

TIME CONSTRAINTS PREVENT ME FROM FURTHER DETAILING OF OUR TOTAL EFFORT IN THOSE AREAS NOW BEING STUDIED, RECOMMENDED OR CONSIDERED FOR IMPLEMENTING. THE THIRTY-ONE (31) MONTH MILESTONE DEVELOPED BY AVONDALE DOES NOT PRETEND TO COMPLETE IN 2½ YEARS WHAT TOOK APPROXIMATELY 18 YEARS TO ACCOMPLISH AT IHI. IT IS ONLY AN INITIAL INCREMENTAL TIME MEASUREMENT ALONG THE WAY.

CHANGES SHOULD COME SLOWLY, AND PARTICULARLY WITH CHANGES IN ORGANIZATION STRUCTURES. THIS IS TRUE WITH ANY DEPARTURE FROM TRADITIONAL METHODS.

SHIPBUILDING, USING THIS PARTICULAR PHILOSOPHY, NEEDS COOPERATIVE ACCEPTANCE BY MANAGEMENT, THE WORK FORCE AND SUPERVISORS FOR ITS SUCCESSFUL EVOLUTION. THIS SEEMS LESS A PROBLEM IN JAPAN WITH JAPANESE WORKERS SINCE THEIR SOCIAL AND TRADITIONAL CUSTOMS HAVE ALWAYS DIRECTED THEM TO THIS OBJECTIVE.

WITH THE AMERICAN WORKER, WE HAVE A MUCH DIFFERENT SITUATION. HIS SOCIAL AND TRADITIONAL CUSTOMS ARE NOT THE SAME. HIS EDUCATION VALUES ARE INDEPENDENTLY ARRIVED AT. HIS COOPERATION, HOWEVER, CAN STILL BE OBTAINED BY INVOLVING HIM AT THE WORKER LEVEL, TO EXPOSING HIM TO THE WORKER PROBLEMS AND TO GIVING HIM A GREATER VOICE IN THEIR SOLUTIONS.

SOLUTIONS THAT PASS Up TO MANAGEMENT AND EVENTUALLY BECOME MANAGEMENT POLICIES IN RECOGNITION OF THE EMPLOYEES EFFORTS.

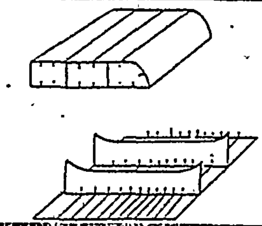
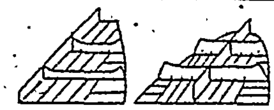
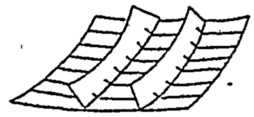
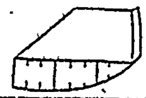
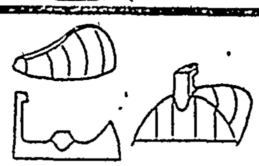
THIS SYSTEM AND, TECHNOLOGY, I AM CONVINCED, WILL INCREASE PRODUCTIVITY; BUT, ONLY IF WE DO IT!

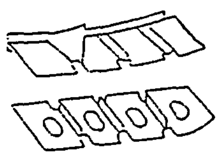
COMPARISON: DESIGN VS. CONTRACT TIME

AVERAGE ASI		AVERAGE IHI	
CONTAINER SHIP			
CONTRACT TIME	34 MOS.	CONTRACT TIME	14 MOS.
DESIGN DURATION	20.5 MOS.	DESIGN DURATION	6 MOS.
PRODUCT CARRIER			
CONTRACT TIME	36 MOS.	CONTRACT TIME	14 MOS.
DESIGN DURATION	20 MOS.	DESIGN DURATION	6 MOS.

HULL CONSTRUCTION BREAKDOWN

MOLD LOFT & CUTTING	10%
SUB ASSEMBLY & ASSEMBLY	50%
ERECTION	40%

CATEGORY	UNIT NAME	SHAPE	BAY
FLAT PANEL UNIT	MIDPART: DOUBLE BOTTOM SIDE SHELL LONG. BHD.		20
SEMI FLAT PANEL UNIT	AFT & FORE PART: DECK, FLAT, T. BHD.		18
CURVED UNIT	AFT & FORE PART: SIDE SHELL		16 17
3 DIM. UNIT	AFT & FORE PART: INNERBOTTOM		17
AFT &FORE END UNIT	BOW CONST. STERN CONST. CANT. CONST.		BUILD. WAY

CATEGORY	SUB UNITS	BAY
ORDINARY SUB 	FLOOR & GIRD OF INNERBOTTOM WEB FR. & GIRD OF SIDE SHELL WEB FR. & GIRD OF DECK WEB FR. & GIRD OF L. BHD. ETC.	14
OTHERS	BUILT UP LONG.	15
	BILGE KEEL RUDDER HAWSE PIPE MAST SEA CHEST BULWARK ETC.	19

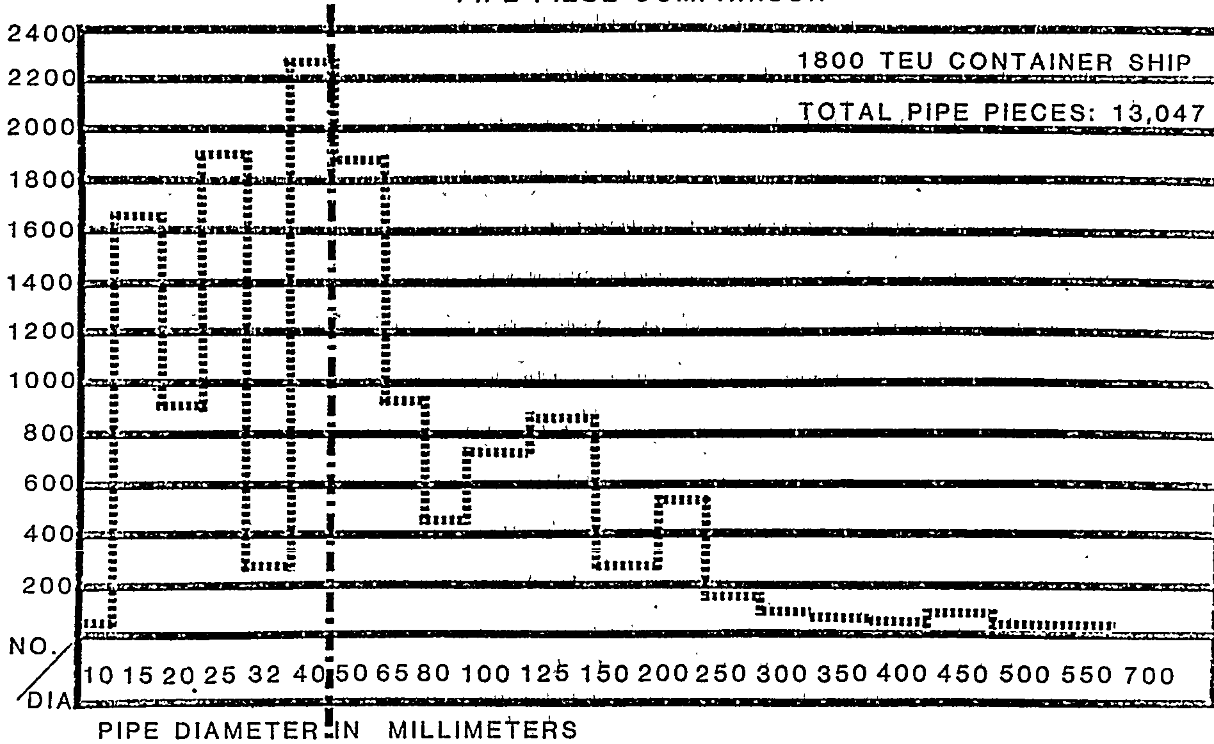
CATEGORY	%	ASS. WT./MONTH (TONS)
FLAT PANEL UNIT	52.8%	4,224
SEMI FLAT PANEL UNIT	8.2%	656
CURVED UNIT	14.8%	1,184
3 DIM. UNIT	8.5%	680
A & F END UNIT	9.6%	768
OTHERS	6.0%	480

ASS. WT. = 8,000 TONS/MONTH

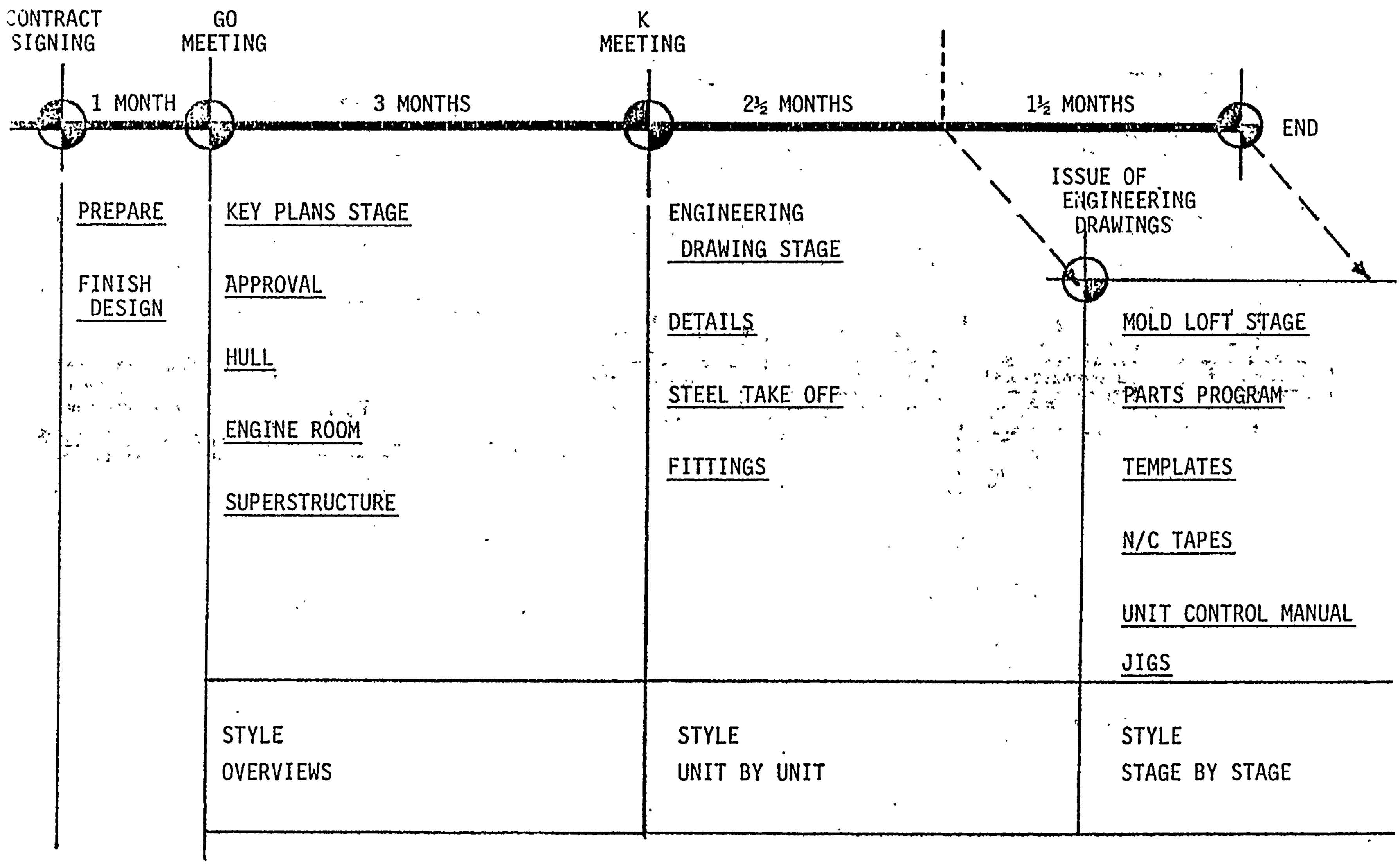
CATEGORY	UNIT NAME		ASS. WT. TON/MONTH	AREA M^2	PRODUCTIVITY OF AREA TON/MONTH M^2
PANEL UNIT	MID PART: D. BOTTOM S. SHELL T. BHD. U.DK.	3K 4K 4W 3W 2W 1A	4,060	7,700	0.53
SEMI PANEL UNIT	A & F PART: DECK, FLAT, T. BHD.	2A	1,314	3,200	0.41
3 DIM. UNIT	A & F PART: D. BOTTOM	3A	450	1,000	0.45
CURVED UNIT	A & F PART: CURVED S. SHELL	1W	1,176	2,700	0.44
			ASS. TOTAL 7,000	14,600	0.48

CATEGORY	ASSWT TON	PRODUCTIVITY OF AREA T/M.M^2	REQD. AREA M^2	BAY	EXISTING AREA M^2
FLAT PANEL UNIT	4,224	0.26(0.53)	16,246	20 & PANEL	16,800
SEMI FLAT PANEL UNIT	656	0.20(0.41)	3,280	18	4,000
3 DIM. UNIT	680	0.23(0.45)	2,960	17	4,750
A & F PART: DOUBLE BOTTOM				16	
CURVED UNIT	1,184	0.22(0.44)	5,380		4,350
A &F END UNIT	768			UP & LOW BUILD. WAY	
OTHERS	480			19	3,100

3 PIPE PIECE COMPARISON



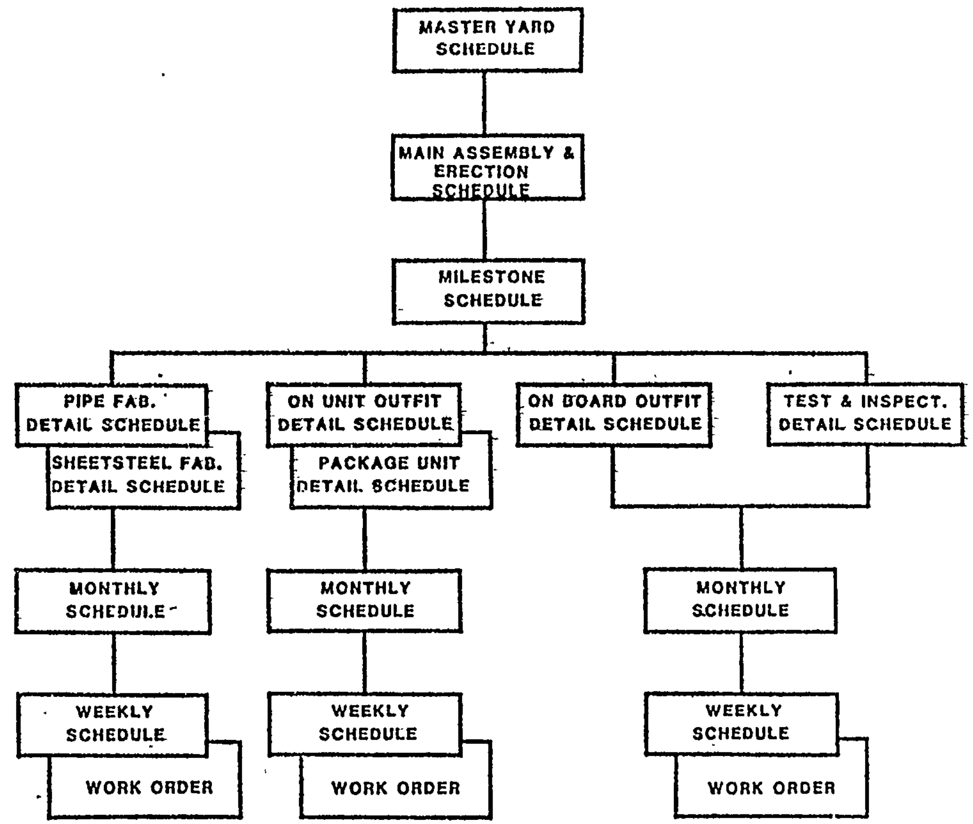
HULL ENGINEERING SCHEDULE
AT AVONDALE SHIPYARDS, INC.



SCHEDULE MEETINGS

☆CHAIRMEN & MEMBERS	DESCRIPTION
☆PROD. PLANNING V.P. PROD. ENG. V.P. & MGR. PROD. V.P. & MGR. PERSONNEL CONCERNED	DECISION OF MILESTONE CHECKING OF PROGRESS HOLD ONCE A MONTH
☆CHIEF OUTFIT PLANNER PROD. ENG. MGR. PROD. MGR. PERSONNEL CONCERNED	DITTO
☆PROD. ENG. MGR. PROD. MGR. CRAFT SUPTS. FOREMEN PERSONNEL CONCERNED	DITTO
☆PROD. ENG. PLANNERS CRAFT SUPTS. FOREMEN PERSONNEL CONCERNED	CHECKING OF PROGRESS AGAINST SCHEDULES

TREE-STRUCTURE OF SCHEDULES



IMPROVING SHIPBUILDING PRODUCTIVITY THROUGH INDUSTRIAL ENGINEERING

Raymond P. Lutz
Executive' Dean of Graduate Studies and Research
The University of Texas
Dallas Texas

Dr. Lutz has served as an Industrial-Engineering consultant for such firms as Republic Steel, Kennecott Corporation, Texas Instruments, and many others. He is an associate member of the American Institute of Industrial Engineers where he has served as Vice President of the Industry and Management Division,

RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING
Philadelphia, Pa.; October 15, 1980

Provisions of the Merchant Marine Act of 1970 charged the Secretary of Commerce with the responsibility to "collaborate with ... shipbuilders in developing plans for the economical construction of vessels." To accomplish this task, the National Shipbuilding Research Program was established by the Maritime Administration with the responsibility to develop improved technical information and procedures for use by U.S. Shipyards, with the objective of reducing the cost and time for building ships. The Ship Production Committee challenged the industry to (1) develop the role of Industrial Engineering in shipbuilding; (2) implement an improved Industrial Engineering capacity; and (3) assist the U.S. shipyards in formulating standards for shipbuilding.

The introduction of Industrial Engineering to shipbuilding or the expansion of the role of Industrial Engineering in shipbuilding continues to the elevation of the level of technology in this industry. There are direct, demonstrable, traceable connections in the progression from high technology to productivity to profitability. This is an economic fact of life which causes some industries to thrive and others to languish or die.

Writing from London, The Economist made the point quite clear recently when it said, "The best job prospects are in those industries that improve productivity fastest. In Britain, the 10 industries that have increased productivity fastest in the past two decades have raised employment by 25%, although employment in British manufacturing as a whole has fallen. 'In the United States, high-technology industries have increased productivity twice as

fast as low-technology ones-and expanded employment nine times as fast. Unions should be asking employers to increase productivity faster, not slower."

The Economist adds, "The people who really are threatening to plunge rich countries into mass unemployment are those who try to shelter dying jobs in sunset industries, and thereby blight the prospects of growth of good jobs in sunrise ones. This includes all Luddite trade unions and politicians, most of the subsidizers of lame ducks, most advocates of import controls."

The need for a strong research and development program in shipbuilding is clear, Our goal is to increase productivity in shipbuilding. Industrial Engineers are dedicated to achieving productivity improvements. The Industrial Engineer integrates the technologies of shipyard operations into an efficient production system to allow us to (A) acquire the desired number of contracts to achieve marketing objectives, (B) to provide ships at a cost which meets or exceeds all profit targets, and (C) to meet all quality and delivery time targets. Satisfying these goals would provide the customer with a dependable product, delivered on time, and at a fair price, while providing a fair return to the shipyard.

To better understand the contributions which the profession of Industrial Engineering could make to increasing shipbuilding productivity, first let us define Industrial Engineering. "Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of people, material, equipment, and energy, It draws upon specialized knowledge and skills in the mathematical, physical, and social sciences together with principles and methods of engineering analysis and design to specify, predict, and evaluate the results obtained from such systems," (AIIE). Working with these systems, it is the objective of industrial engineering to achieve the goals and objectives of management. Industrial Engineering then advances technology through people,

To demonstrate that the application of Industrial Engineering technology could increase shipyard productivity, it was decided that the

initial effort would be directed toward studying work methods and establishing engineered job standards. Six yards were chosen as demonstration sites to develop job standards for particular areas of work. Not only would these six pilot projects test the impact of introducing job standards, but they would also provide standards information to all yards. Everyone could benefit without costly duplication of effort.

The purpose of establishing job standards is fourfold: (1) to develop the lowest cost system or method to perform the work; (2) to standardize the system or method to produce reliable forecasts of future costs and a valid basis for cost control; (3) to determine the time required by a qualified and properly trained person, working at a normal pace to do a specific task or operation; and (4) to assist and train the worker in performing the specified task using the preferred method. Standards can be used to set prices, plan production, and estimate capacity and manpower needs. Consequently, work standards should be a foundation for the entire shipbuilding operation.

A response I often hear when recommending the establishment of job standards is "putting in job standards is a waste of money. My people know how to do their job!" Right: Everyone knows how to make up a bed, wash a sink and vacuum a floor, but the Holiday Inn Southeast in Nashville saved a net of $100,000 per year by studying the maids' job and putting in improved methods and standards. As the manager said "It wasn't the guests wearing out our carpets, it was the maids." From a level of 13 to 14 rooms/day, each maid now cleans 20 to 22 rooms/day and has extra time to check on and initiate needed room maintenance. This is a result of improved methods and establishing standards.

I.K.D. Corp., a metal fabricator, increased productivity 48% through engineering methods. Their industrial engineers studied a job which had not changed in 7 years. They made a change to fluxcore welding from stickwelding equipment and changed the work place layout. A 35% increase in productivity was accomplished through work measurements and setting standards on the same operation.

Likewise, in shipbuilding there have already been significant

improvements in productivity just as a side benefit of the methods and labor standards development program.

- 25 to 30% productivity improvement in crane utilization from the use of time studies to identify delays. As a result, more emphasis was placed on planning the crane moves and the riggers were prompted to be better prepared and set up for each crane usage,
- 10 to 40% productivity improvement in the shipboard assembly and installation 'area, resulting from a methods analysis performed while defining the process used in work measurement. Using the most efficient process also established proper manning requirements and a better definition of material requirements, palletizing, and staging needs.
- 15% productivity improvements were realized in the foundation assembly area. Some examples of methods improvements contributing to this overall productivity improvement rate are:

  Installation of jib cranes to service work tables to eliminate the delays caused by using the bridge crane.

  Setting up a clipboard logging system for fabricated parts replacing random storage, thus improving the flow of parts to the assembly work area.

  Method change in fabrication of deck beam cutouts from burning to more efficient punching out of cutouts with a punch press. This process also reduces slag grinding time at assembly.

  Switching from stick welding to more efficient fluxcore welding with the introduction of new fluxcore equipment.

  Relocation of various equipment and work benches to allow a better flow of material.

These are conservative estimates from actual shipyard documentation. With the introduction of a cost reporting system and the use of the MOST Computer System during Phase II of this program, much greater returns are anticipated within the shipbuilding industry in the following years through the use of these computerized standards to support activities in welding, production scheduling and tither shipbuilding functions, Work standards are not required to do a job. Work standards are only required if the objective is to do a job better, at a lower cost.

If you aren't taking advantage of the labor standards program, you are missing a critical bet. The application of industrial engineering techniques can save significant dollars., as the improvements in the six yards using MOST have already demonstrated. More emphasis in the future will be placed upon applying job standards to a wider range of activities. Stress will be placed upon establishing consistent and accurate job standards to previously unstandardized functions. An example of this is Florida Power & Light now has 85% of its non-supervisory jobs under standards. $900,000/year net audited savings has been realized by applying standards to clerical, service, and maintenance jobs. The Air Force's insistence on implementing Military Standard 1567 stated job standards will be set for more clerical and white-collar tasks, as the cost of these tasks rise in proportion to direct labor costs of manufacturing.

The impact of the development of methods and standards through Mil Std 1567 has already been demonstrated. This past week Boeing reported an increase of 20% in 2 years in one shop alone. They have already achieved a gross savings of $31.3m for an implementation cost of $1.8m. Boeing executives estimate a discounted return on their investment over the life of the project to be $17. for each $1 invested. Needless to say, they are quite pleased with the, program.

The results to date of the Mil Std 1567 remind me of the mother who forces her child to eat a balanced diet. While the objections to these directives maybe long and loud, the benefits are real and the good habits stay with the individual for a lifetime.

Work measurements, and methods engineering is the cornerstone of industrial, engineering activities and will have the highest immediate payoff of all industrial engineering functions to shipbuilding. These techniques provide the data for (1) preparing bids, (2) improving methods to increase productivity and, lower costs, and (3) monitoring and controlling the production operations.

The work measurement system is critical to the operation of all other functions. However, WMME. is not the only IE function. In the remainder of this presentation I would like to provide you with an overview of typical savings which have been achieved in, other industries through the expanded, application of other Industrial Engineering functions.

Just as in the application of work measurements and methods engineering, significant savings, are available through improvements in the material flow system. By redesigning their material flow system for one operation at I.K.D. Corp., the industrial engineers were able to increase productivity in that operation by 101% in 1979. This item was a low volume, heavy metal fabrication which was moved on large carts between various cutting, welding, assembling and finishing areas. The carts were actually used more for storage than for transportation. The result was crowded, poorly organized work places., The operators spent a very large percentage of their working day looking for, and moving materials. The industrial engineers flow charted this operation, analyzed it, prepared templates and layed out the work place. They achieved a better. operation and developed a place for all materials required in the process. Under the original layout an average of,, 1.4 man-hours were required. By the 5th week, it took 69 man-hours. Then by taking time studies, a final standard. of O.67 man-hours/unit *was* developed. *The* standard was attained; because of the more efficient, layout, a six-fold increase in capacity was also possible in-the same floor, space allowing the cancellation of a proposed shop expansion.

The industrial engineer has improved both the design and management of material handling systems for more efficient materials flow. For example, Maytag was able to reduce the initial cost of a proposed material

handling system for sheet metal by 23% ($3.2 million) through a computer simulation of material flow. This simulation showed that by careful material management, 23% of the proposed material handling equipment was unnecessary.

Black and Decker was concerned with one aspect of their production control system stored parts availability. They had the following objectives:

Reduce overall operating -cost

Reduce clerical efforts in records and audits

Provide data on current material availability status, and make these data available throughout the plant

Their industrial engineers took this $14 million inventory and developed a computerized control system which

Increased storeroom labor productivity 15%

Increased space utilization

Reduced "Balance on Hand" discrepancies from 3000 to an average of 100

Cut lead time of material in the staging area from 3 weeks to 1 week.

Increased expeditures response to manufacturing needs, and

Reduced expediting of material obsoleted by engineering change orders.

They wanted to plan and sequence material where and when it was needed for the assembly operation.

Florida Power and Light saved $13.5 million annually in inventory carrying Costs by using a computerized "what-if" model to test an idea from an Industrial Engineer, This idea used a central stores warehouse and control system for the 20,000 items in their 53 distribution centers. By better control they increased inventory turns by 300% (0.86 to 3.5) and reduced the value of the inventory they would have to carry by 48%. They also eliminated the need for rented space.

Scheduling control of the machine shop proposed by an Industrial Engineering organization in one of our shipyards recently would result in a payback of less than a year for all of the-computer hardware and

software necessary to implement the proposed scheduling procedure.

Forklift trucks are a neglected million dollar resource, at least in terms of replacement value. IBM at San Jose had 50 and were planning to expand to 100; yet, had no record of departmental utilization. The -only truck records were the oil stained logs kept by the mechanics.- With maintenance costs less than 0.4% of the operating budget, these trucks got little management attention until someone wanted to spend $25,000 'for a new truck,.

Justification data just wasn't available.' Every competing manager then became a truck expert. The result was one more welding job to patch up the old forklift until it fell apart. Then, upon final failure, emergency funds were used to buy a new one from the dealer's stock, one which probably didn't have all the features which were needed. Consequently, the old truck was probably resurrected and used as a "high-cost" spare.

The dealer won. The foreman, driver, and company lost. IBM realized a 30% annualized cost reduction in fork lifts after their industrial engineers initiated a cost collection system and a program of replacement analysis. These cost savings resulted from;

(1) Reduction in total number of trucks through-better utilization (also they now have never and better trucks),

(2) Replacement of old high maintenance trucks

(3) P eventive maintenance program based on usage

(4) Inventory system for spare parts, and

Adequate maintenance facilities to test the feasibility of this proposed system.

Bethlehem Steel recently used a simulation model to determine their equipment requirements and material flow in their Lackawanna Plant Billet Yard. They considered items in the model such as:

Equipment Capacity

Facility Layout

Crane Utilization

Travel Distance

Interference Measures

Queue Statistics

Resource Utilization

Down Time Statistics

Fortunately, an extensive base of standard data for methods and times were available for the various operations in the proposed facility. Consequently, an accurate and effective analysis of the operation of the proposed Billet yard was possible.

The model showed that the target capacity of the yard couldn't be achieved because of the bottleneck of grinder capacity. However if they were eliminated, capacity would still be limited below target by crane availability.

The Billet yard was then completely redesigned and is now operating successfully. The cost of the simulation was trivial compared to the cost of either missing production output targets or of reworking an installed facility, Bethlehem is now using this model to design its Johnstown Plant.

R. & G. Sloane, a California manufacturer of pipe fittings, built their production information system to schedule material arrival and control inventory. They increased inventory turns 25% and raised the on-time delivery schedule by 10% to 94% of total shipments. By building a management information system for the firm from their original production information system and by using it to analyze the most profitable profit mix, they added $500,000 to net profits in 1978. However, be advised that they had to wait 6 months to use their computerized MRP Scheduling program because they didn't have good data in the systems

International Paper has gotten back $100 for every $1 invested in their system over a 5 year period.

Again, you must develop the cost data through job standards and cost accounting, build the model, and use 'it to ask "Whht if" questions to support managerial decision-making. To provide these data firms are computerizing their predetermined time standards for a comprehensive

data base of task related information. Baxter Travenol Labs saves $800,000/year after-computerizing their -data base in 1978. The introduction of computerized MOST in Phase II will give the shipyards the opportunity to develop simulation models and ask these "What If" questions. The effort should be worth it in the profits derived from better decisions.

This set of examples was intended to illustrate the impact the application of Industrial Engineering techniques could have upon the productivity and profitability of the firm. Shipyards should be able to achieve at least these savings by going- into an organized program to implement Industrial Engineering techniques into their operations. Work measurements and methods engineering activities are just a first step, albeit an important one. The Industrial Engineer is involved in a multitude of functions, entailing a knowledge of both the technical and human side of the operation, It is this combination of technical and human functions which will put us on target for productivity.

What should the I.E. deliver? The Delco Division of General Motors charges each industrial engineer to submit and implement at least $50,000 of direct cost reduction items per year. DuPont requires each industrial engineer to propose cost savings equal to 10 times his salary. Given this potential the combined effect on productivity improvement through the sound application of the techniques found in both the technical and human functions can provide an ever improving productivity and profitability for our shipyards. The potential is there, we only have to exploit the potential.

To achieve the desired objectives, it is necessary to have both "motivation and movement." These can be developed through establishing an operating industrial engineering organization. You must have this industrial capability "in-house."

It is important to "hit home runs" by picking projects with the greatest payoff. Gaining momentum from initial successes is critical. A prime example of home run potential is the current effort to establish job standards. Productivity increases of 10% to 40% should provide

that initial momentum and demonstrate the savings possible through the application of industrial engineering techniques. Further, job standards provide the base data for utilizing the other function of industrial engineering. Shipyards will reap future savings through using those standards, for example, in MRP production scheduling and computerized simulation and decision models. Consequently, those yards now establishing standards should be planning for their next "great leap forward," using their standards as a base for the application of other industrial engineering functions. The industrial engineer through leadership, reinforced with a positive attitude, can contribute significantly to effectiveness and profitability in shipbuilding.

AN OVERVIEW OF THE MANUAL AND THE COMPUTER "MOST" WORK MEASUREMENT SYSTEMS

William M. Yates Jr
Sales Coordinator
H. B. Maynard and Company Inc
Pittsburgh, Pennsylvania

Mr. Yates has the responsibility for the administration of all company sales information and reports. He aids the sales staff with computer systems configuration and proposal preparation. He also provides presentations and demonstrations of H. B. Maynard and Company services to potential clients as well as interested professional organizations.

Mr. Yates holds a degree in administration from the University of Pittsburgh, and 'is a graduate of Carnegie-Mellon University.

MOST®
COMPUTER
SYSTEMS

A NEW AUTOMATED
SYSTEM FOR THE ESTABLISHMENT AND
MAINTENANCE OF ENGINEERED LABOR TIME STANDARDS

H. B. MAYNARD and COMPANY, INC.

INTERNATIONAL MANAGEMENT CONSULTANTS

WHY DO WE NEED LABOR TIME STANDARDS?

- SATISFY A BASIC HUMAN CHARACTERISTIC (THE NEED TO KNOW WHAT IS EXPECTED FROM A PERSON)
- PLAN AND SCHEDULE LABOR REGARDING TIME AND MANPOWER
- CONTROL OUTPUT AND PRODUCTIVITY
- CALCULATE PRODUCT AND LABOR COSTS
- PAY BY RESULTS

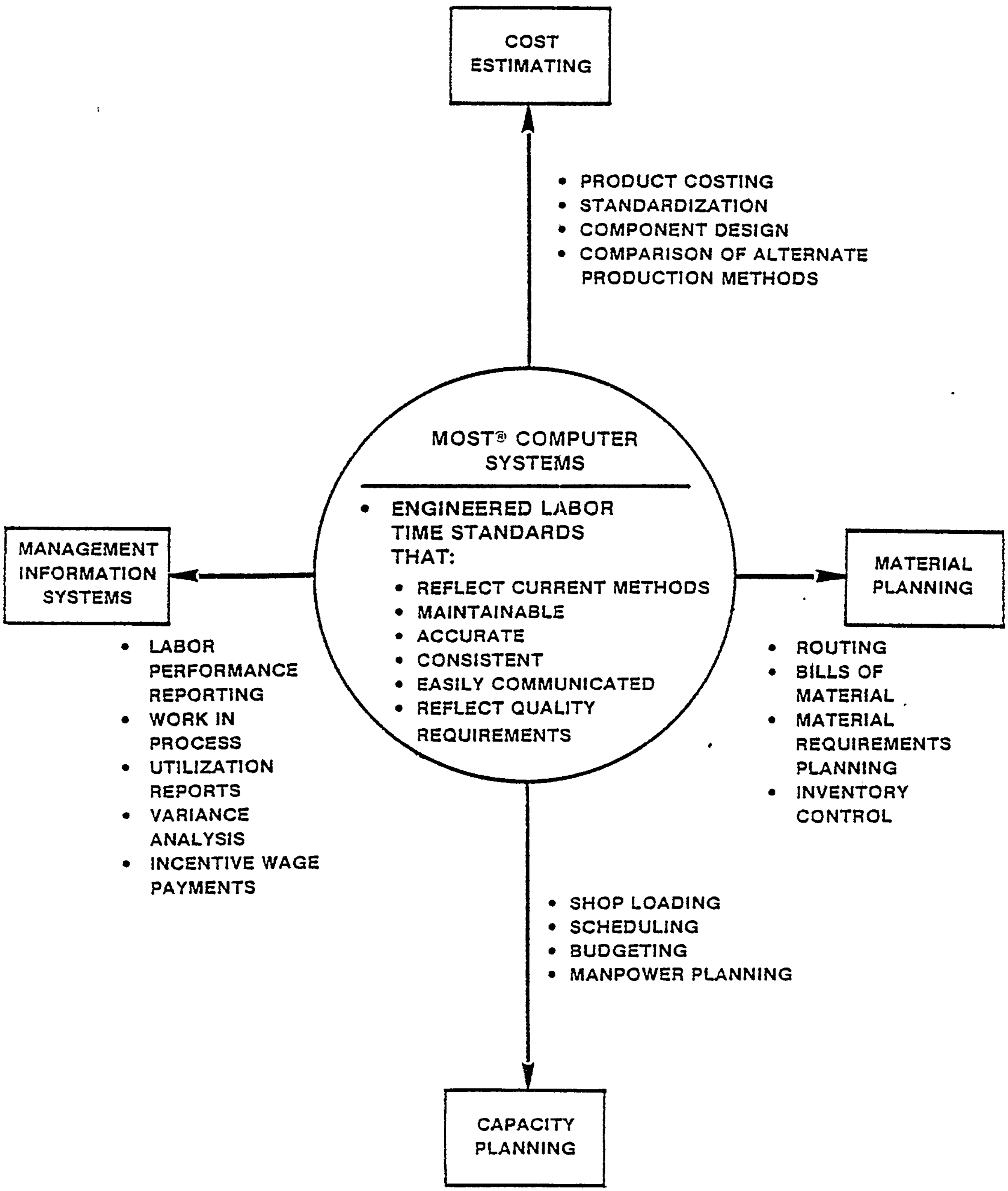
WHAT IS REQUIRED TO CALCULATE AN ENGINEERED TIME STANDARD?

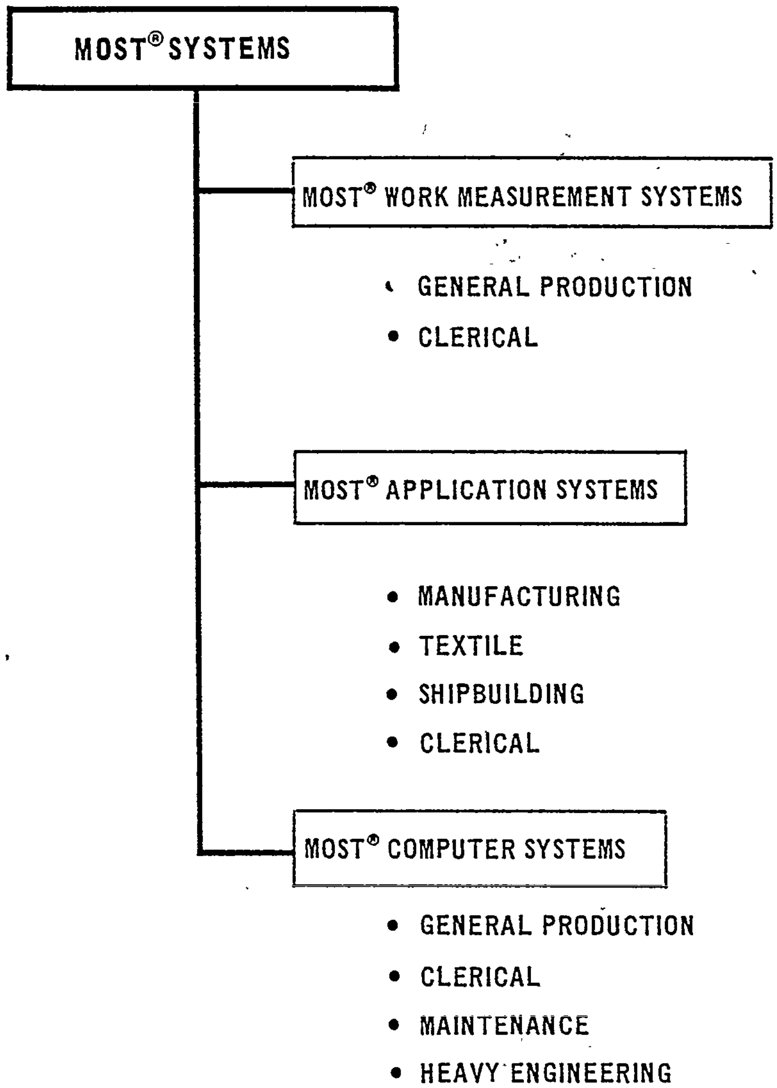
1. DOCUMENTATION OF WORK CONDITIONS
2. WORK MEASUREMENT TECHNIQUE (MOST)
3. SUB-OPERATION DATA DEVELOPMENT PRINCIPLES AND RULES
4. FILING SYSTEM FOR SUB-OPERATION DATA
5. CALCULATION FORMATS FOR FINAL TIME STANDARDS

'MOST' SYSTEMS

- TIME STANDARDS
- WORK MANAGEMENT
- PRODUCTION CONTROLS
- PRODUCTIVITY IMPROVEMENTS
- INVESTMENT PAYOFF < ONE YEAR

MOST® COMPUTER SYSTEMS





MOST SYSTEMS FAMILY

'MOST' FEATURES

- <u>UNIVERSAL</u> APPROACH
- <u>FAST</u> TO APPLY
- <u>ADEQUATE</u> ACCURACY
- <u>EASY</u> TO UNDERSTAND AND LEARN
- <u>MINIMUM</u> OF PAPERWORK
- <u>MULTILEVEL</u> SYSTEM
- <u>CONSISTENT</u> RESULTS
- <u>ENCOURAGE</u> METHODS DEVELOPMENT
- <u>OPEN</u> TO SUPPLEMENTS
- <u>ECONOMIC</u> INSTALLATION

MOST® COMPUTER SYSTEMS

WILL -

- **SIMPLIFY AND ACCELERATE THE DEVELOPMENT AND MAINTENANCE OF TIME STANDARDS**

- **IMPROVE THE PRODUCTIVITY OF THE INDUSTRIAL ENGINEER**

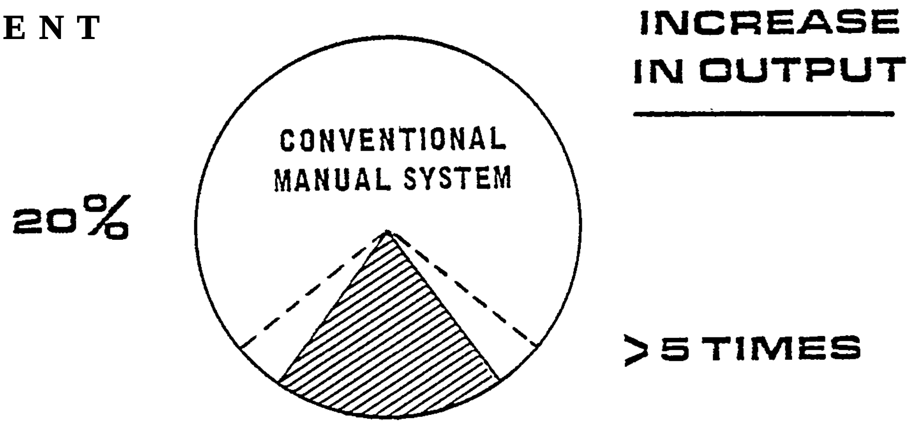
- **MAKE THE INDUSTRIAL ENGINEER'S JOB MORE CHALLENGING AND STIMULATING**

- **GENERATE UNIFORM INFORMATION AND DATA FOR FASTER AND MORE CONSISTENT PRODUCTION PLANNING AND CONTROL**

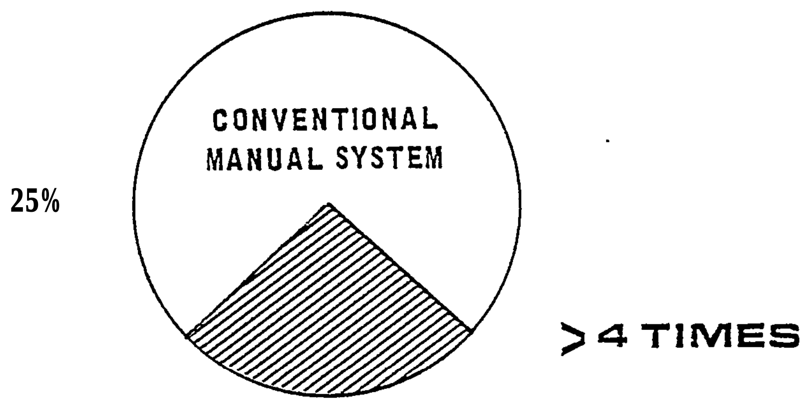
- **INCREASE THE SAVINGS/COST RATIO FOR THE INDUSTRIAL ENGINEERING FUNCTION AND THE PROFITABILITY FOR THE COMPANY**

REDUCED MANPOWER REQUIREMENTS FOR:

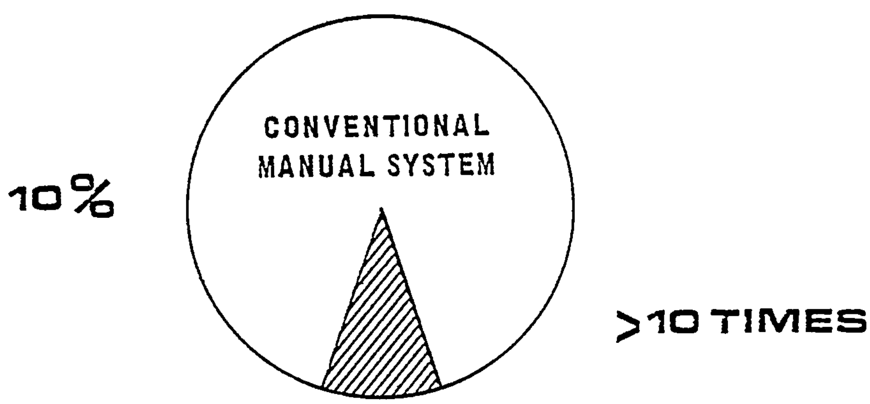
DEVELOPMENT

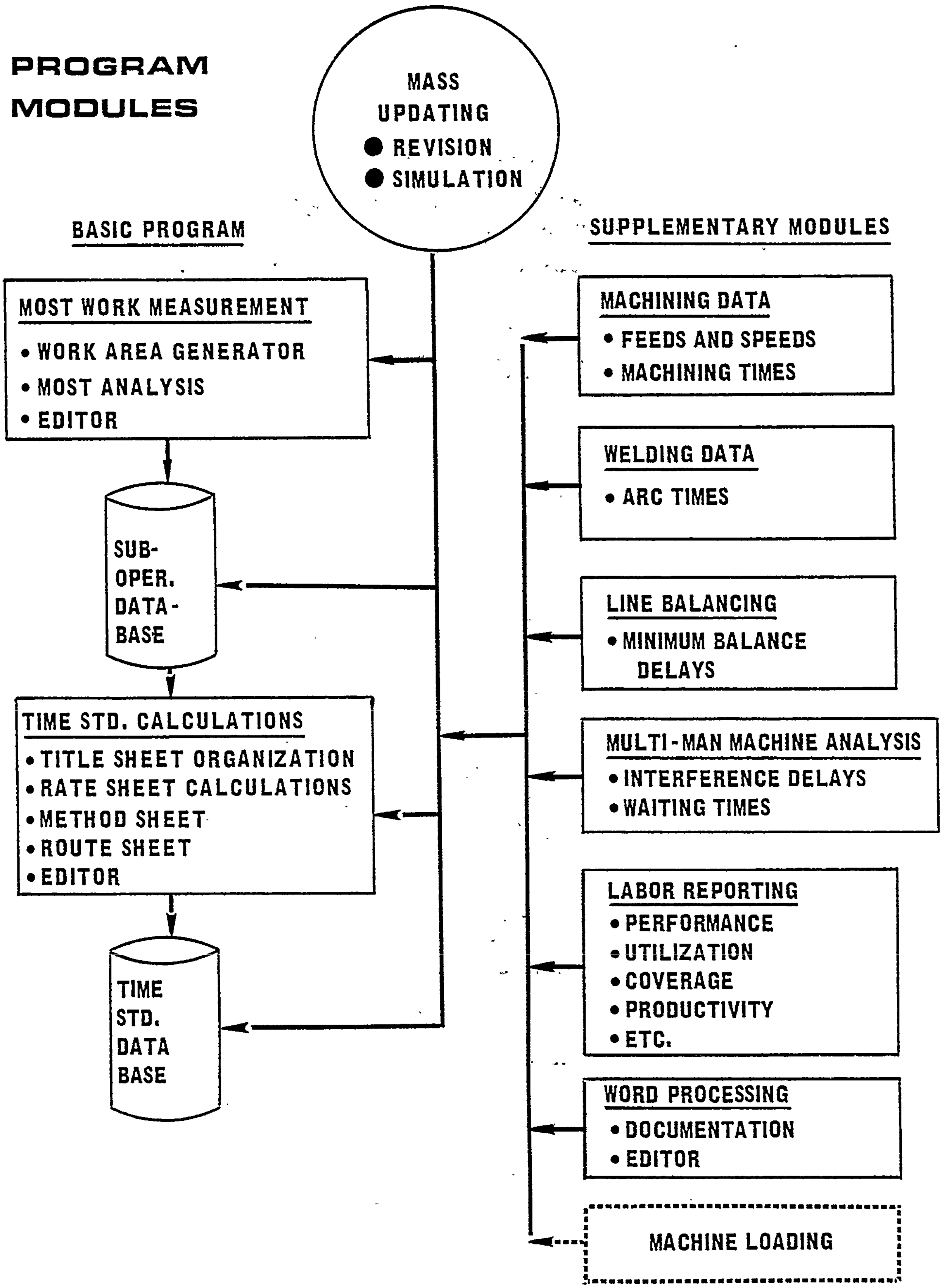


APPLICATION

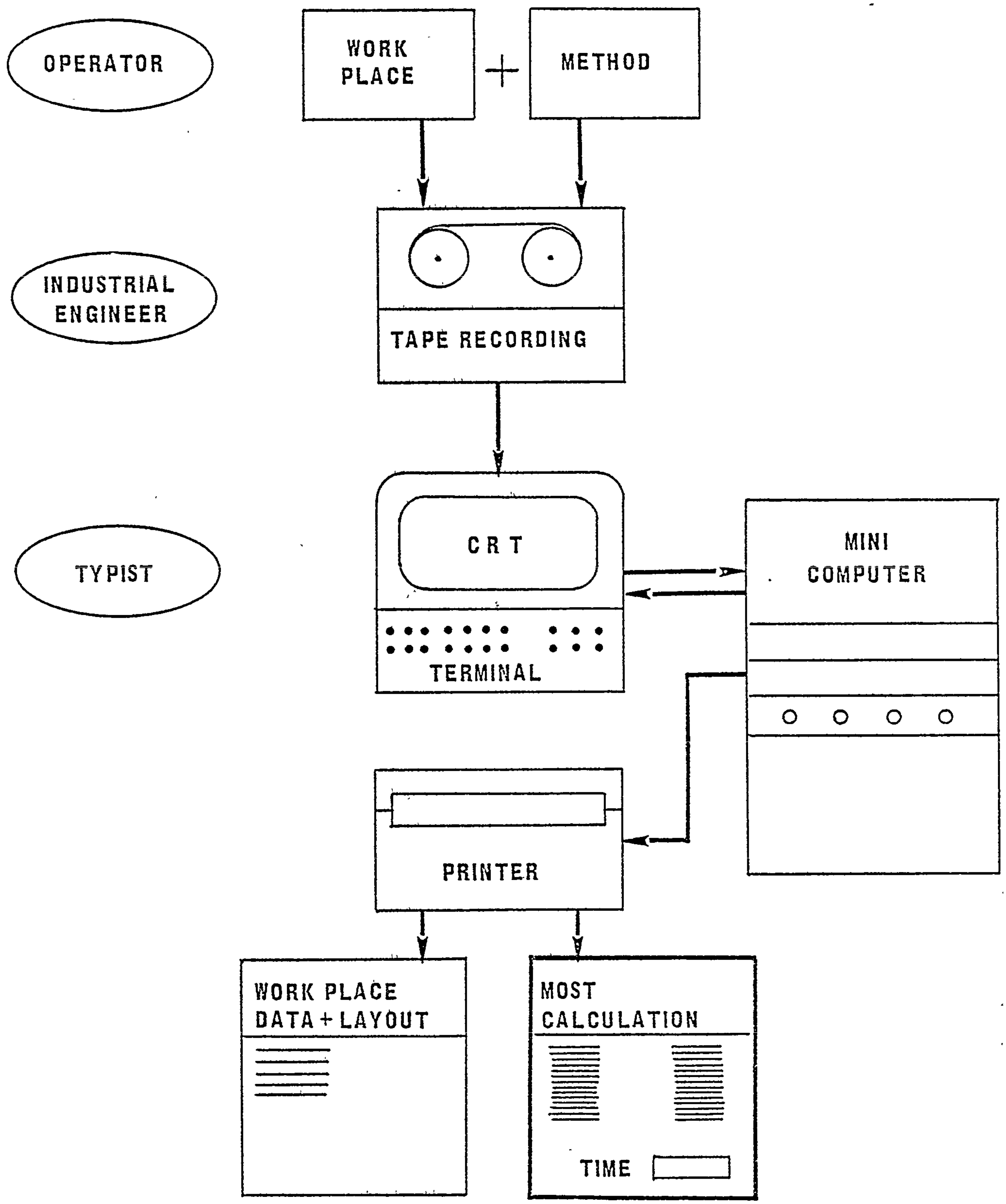


MAINTENANCE



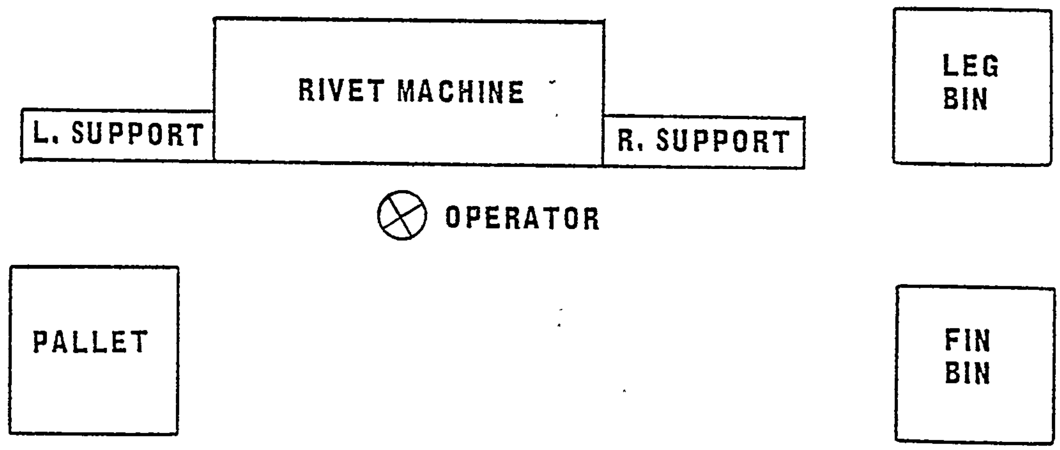

PROGRAM
MODULES
MASS
UPDATING
● REVISION
● SIMULATION
BASIC PROGRAM
SUPPLEMENTARY MODULES
MOST WORK MEASUREMENT
• WORK AREA GENERATOR
• MOST ANALYSIS
• EDITOR
SUB-
OPER.
DATA-
BASE
TIME STD. CALCULATIONS
• TITLE SHEET ORGANIZATION
• RATE SHEET CALCULATIONS
• METHOD SHEET
• ROUTE SHEET
• EDITOR
TIME
STD.
DATA
BASE
MACHINING DATA
• FEEDS AND SPEEDS
• MACHINING TIMES
WELDING DATA
• ARC TIMES
LINE BALANCING
• MINIMUM BALANCE
DELAYS
MULTI-MAN MACHINE ANALYSIS
• INTERFERENCE DELAYS
• WAITING TIMES
LABOR REPORTING
• PERFORMANCE
• UTILIZATION
• COVERAGE
• PRODUCTIVITY
• ETC.
WORD PROCESSING
• DOCUMENTATION
• EDITOR
MACHINE LOADING

BASIC DATA ENTRY



ANALYSIS EXAMPLE

WORKPLACE: RIVET MACHINE



WORK STATIONS:

RIVET MACHINE	12/6, 6/3
LEFT SUPPORT	8/6, 4/1
RIGHT SUPPORT	16/6, 4/1
PALLET/BEND	8/2, 4/4
LEG BIN	22/6, 4/4
FIN BIN	22/2, 4/4

OPERATOR 15/6

ACTION DISTANCES:

FIN BIN - PALLET	3 STEPS
FIN BIN - R. SUPPORT	2
FIN BIN - L. SUPPORT	2
FIN BIN - RIVET MACH,	2
FIN BIN - LEG BIN	2
PALLET - R. SUPPORT	2
PALLET - L. SUPPORT	2
PALLET - RIVET MACH.	2
PALLET - LEG BIN	2

EQUIPMENT:

RIVET MACHINE - PT =.5 SEC.

TOOLS:

NONE

PARTS/OBJECTS:

PALLET -ANGLES

RIVET MACHINE - RIVET PINS

LEG BIN - LEGS

FASTEN WITH RIVETER 107/1005/2

RIVET 2 LEGS TO CENTER SUPPORT

1	PLACE 1ST LEG TO RIVETPINS AND LEFTSUPPORT	A3	B0	G1	A1	B0	P3	A0	1.0	80
2	PLACE ANGLE FROM PALLET TO RIVETPINS F 2	A3	B6	G1	A3	B0	P3	A0	2.0	320
3	PUSH FOOTPEDAL FOR RIVETING LEG	A1	B0	G1	M1	X1	I0	A0	1.0	40
4	HOLDMOVE ANGLE FROM RIVETMACHINE TO RIGHTSUPPORT	A0	B0	G0	A1	B0	P1	A0	1.0	20
5	PLACE 2ND LEG AND ANGLE TO RIVETPINS	A1	B0	G1	A1	B0	P3	A0	1.0	60
6	PUSH FOOTPEDAL FOR RIVETING LEG	A1	B0	G1	M1	X1	I0	A0	1.0	40
7	HOLDMOVE LEG ASSEMBLY TO FINBIN	A0	B0	G0	A3	B0	P1	A0	1.0	40

TOTAL TMU 600

MANUAL HANDLING		
ACTIVITY	SEQUENCE MODEL	SUB-ACTIVITIES
GENERAL MOVE	ABGABPA	A - ACTION DISTANCE B - BODY MOTION G - GAIN CONTROL P - PLACE
CONTROLLED MOVE	ABGMXIA	M - MOVE CONTROLLED X - PROCESS TIME I - ALIGN
TOOL USE	ABGABP ABPA	F - FASTEN L - LOOSEN M - MEASURE R - RECORD S - SURFACE TREAT T - THINK

MOST® COMPUTER SYSTEMS FILING PROGRAM CATEGORIES FOR SUB-OPERATION DATA UNITS

		EXAMPLE
	● ACTIVITY(IES)	EXCHANGE
MAJOR CATEGORIES	● OBJECT(S)/COMPONENT(S) in/on/for	WORKPIECE in
	● EQUIPMENT/PRODUCT with	3-JAW CHUCK with
	● TOOL(S) from/to/at	T-WRENCH at
	● LOCATION	ENGINE LATHE #341
SUPPLEMENTARY DATA	● PER unit	PER part
	● OCCURRENCE FREQUENCY GROUP	OFG 2
	● DATE	11/7/77
	● SPECIAL USER CATEGORY(IES)	(APPLICATOR, PLANT, ETC.)
	● CONDITIONS	(RESTRICTIONS, SPECIAL APPLICATIONS, ETC.)

MOST” COMPUTER SYSTEMS
FILING CATEGORIES FOR TIME STANDARDS

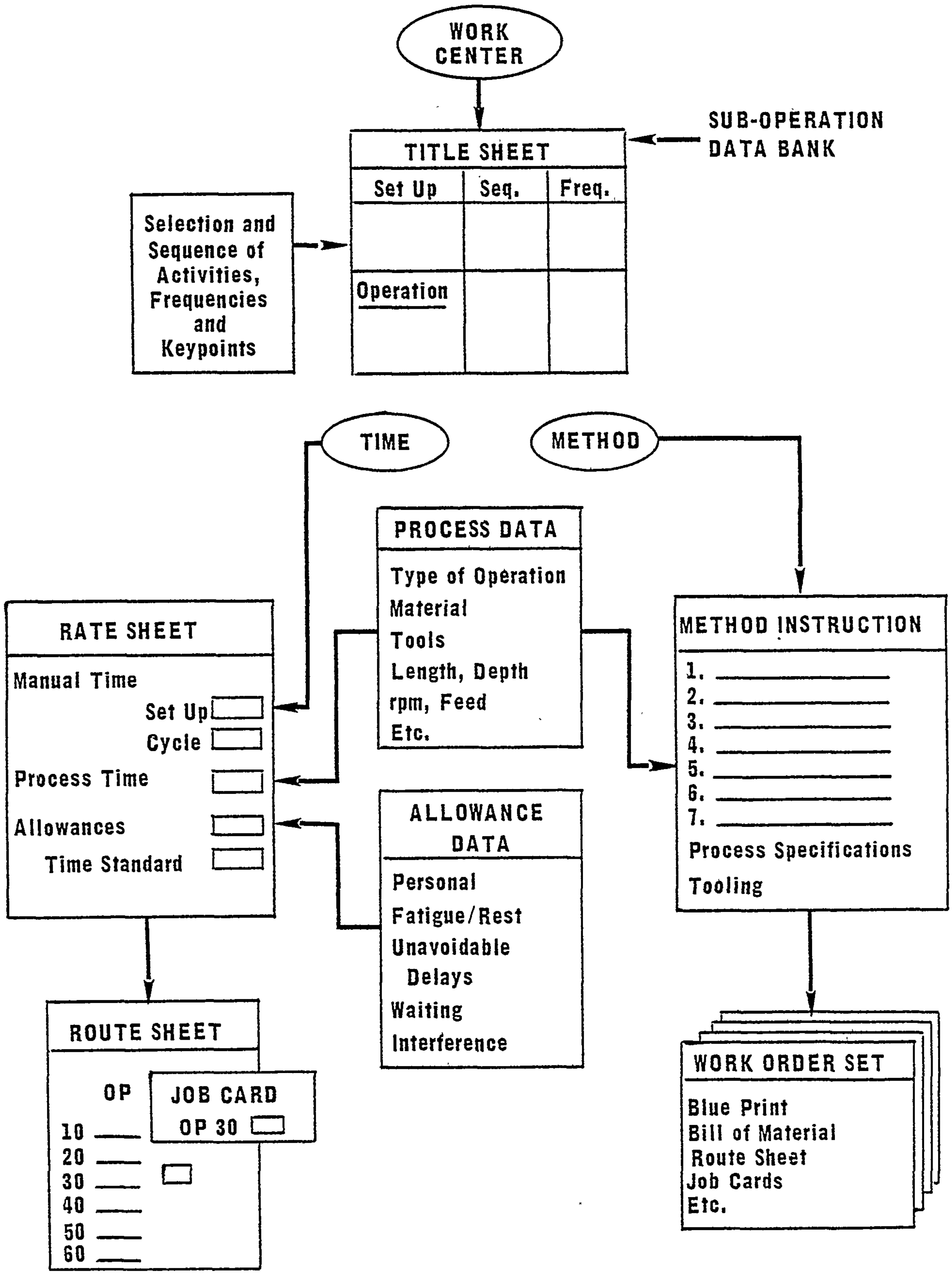
- PRODUCT/SUBASSEMBLY/PART NUMBER
- PRODUCT/SUBASSEMBLY/PART NAME
- COMPONENT CLASSIFICATION NUMBER

- PLANT NUMBER
- DEPARTMENT NUMBER
- COST CENTER NUMBER
- WORK CENTER NUMBER

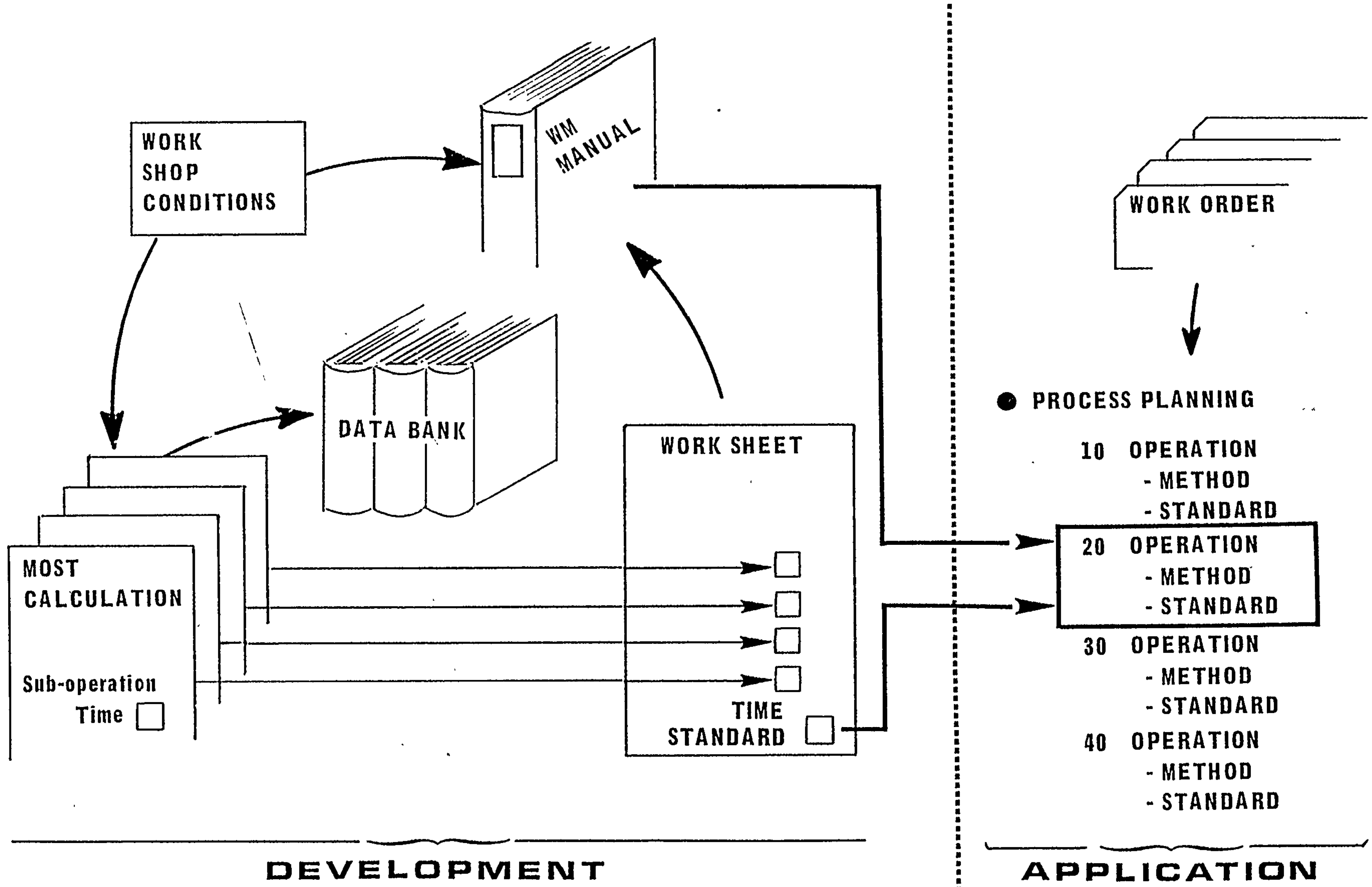
- BILL OF MATERIAL NUMBER
- ROUTE SHEET NUMBER
- OPERATION NUMBER

- OPERATION NAME

PROCEDURE FOR ESTABLISHING METHODS AND TIME STANDARDS

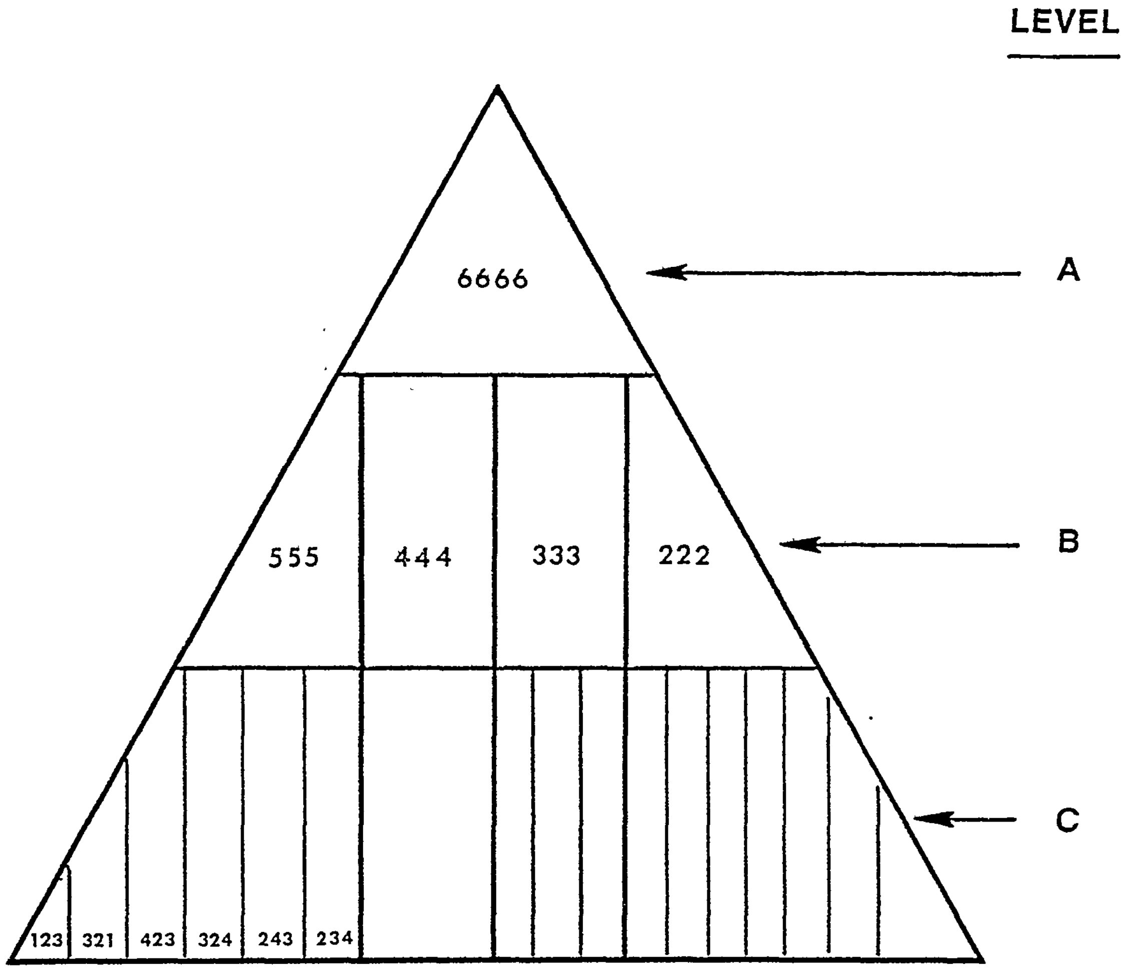


PROCEDURE FOR DEVELOPMENT & APPLICATION OF STANDARDS



SHIPBUILDING

MOST@ APPLICATION LEVELS



A - INDIVIDUAL STANDARDS COMBINED FOR WORK PACKAGE APPLICATION - APPEAR ON THE STANDARDS CALCULATION SHEET

B - FINAL COMBINED MOST ANALYSES

C - INDIVIDUAL OR COMBINED MOST ANALYSES

COMPUTER MOST
APPLICATION SHEET
FITTING

TITLE SHEET LOCATOR NUMBER 4321

MAJOR CATEGORY	NO.	DESCRIPTION	PER	LOCATER NO.
	1	INSTALL REINFORCEMENT RING	RING	6666
RINGS	2	MAKE-UP REINFORCEMENT RING	RING	7777
	3	______	______	______
PLATES	4	MAKE-UP FACE PLATE TO WEB OR SECTION PART	FOOT	9999
	5	______	______	______
	6	______	______	______
	7	______	______	______
	8	______	______	______
______	______	______	______	______

LEVEL					
0 A		LN	6666	COMB SUB-OPERATION	FR
			555	MAKE-UP RING	1
	COMB		444	GRIND	1
0 B	SUB-		333	INSTALL RING	1
	OPERATIONS		222	GRIND	4
0 B		LN	555	MAKE-UP RING	FR
			123	MOVE	1
			321	MEASURE	2
	COMB		423	FIT	4
0 C	SUB-		324	TACK	4
	OPERATIONS		243	INSPECT	2
			234	ASIDE	1

WHY SHOULD YOU USE MOST® COMPUTER SYSTEMS?

(1) BECAUSE MOST@ COMPUTER SYSTEMS CAN:

- PROVIDE YOU WITH ACCURATE AND CONSISTENT WELL-DOCUMENTED TIME STANDARDS AND METHODS DESCRIPTIONS

- PROVIDE YOU WITH REALISTIC TIME STANDARDS FOR COSTING, SCHEDULING, MANPOWER PLANNING, PERFORMANCE CONTROL, WAGE INCENTIVES, ETC., E.G., THE BASIS FOR YOUR "MANUFACTURING INFORMATION SYSTEM"

- PROVIDE YOU WITH EASY-TO-READ METHOD INSTRUCTIONS FOR YOUR OPERATORS, ROUTE OR PROCESS SHEETS AS WELL AS WORKPLACE LAYOUTS AND DATA

- PROVIDE YOU WITH AN EXTREMELY COST EFFECTIVE SET OF LABOR TIME STANDARDS WITH SAVINGS OF:

  25% - DEVELOPMENT
  75% - APPLICATION
  90% - MAINTENANCE

  COMPARED TO A MANUAL APPLICATION

- PROVIDE THE BASIS FOR A COMPREHENSIVE INCENTIVE CORRECTION PROGRAM WITHIN REASONABLE TIME AND COST

- PROVIDE YOUR UNION AND/OR WORKER REPRESENTATIVES WITH FULL KNOWLEDGE AND PROPER APPLICATION EXPERIENCE TO ENHANCE THEIR UNDERSTANDING AND INVOLVEMENT IN THE IMPLEMENTATION

- PROVIDE THE OPPORTUNITY FOR EITHER A COMPUTERIZED OR A MANUAL APPLICATION ALIKE

- PROVIDE A UNIFORM APPLICATION IN MULTI-PLANT ORGANIZATIONS AS A RESULT OF YOUR 'CENTRAL COORDINATION AND INSTANT INTERCHANGE-ABILITY OF COMPUTER STORED DATA

WHY SHOULD YOU USE MOST® COMPUTER SYSTEMS ?

(2) BECAUSE YOU CAN:

- PRE-SET COMPLETE ENGINEERED TIME STANDARDS INCLUDING MANUAL, PROCESS AND ALLOWANCE TIMES AND KEEP THESE STANDARDS UP-TO-DATE WITH A MINIMUM Of EFFORT

- DOCUMENT ALL YOUR WORKSHOP CONDITIONS AND DATA FOR RAPID AND NEAT PRINTING AND UPDATING TO BE USED FOR INSTRUCTIONS AND REFERENCING AS WELL AS THE BASIS FOR FURTHER COMPANY-WIDE DEVELOPMENTS

- ADAPT PROGRAM OUTPUT FORMATS TO YOUR PRESENT ESTABLISHED PROCEDURES AND ROUTINES

- SIMULATE POSSIBLE PRODUCTIVITY IMPROVEMENT OPPORTUNITIES IN YOUR MANUFACTURING AREAS, A KEY TASK FOR YOUR INDUSTRIAL ENGINEERS

- INCREASE YOUR INDUSTRIAL ENGINEERS' OUTPUT AND PRODUCTIVITY AS WELL AS IMPROVE THE QUALITY OF THEIR WORK

- ATTRACT NEW AND QUALIFIED INDUSTRIAL ENGINEERING ‘CAPACITY AS WELL AS KEEP YOUR COMPETENT INDUSTRIAL ENGINEERING PERSONNEL

- INCORPORATE MODERN COMPUTER TECHNOLOGY IN YOUR INDUSTRIAL ENGINEERING DEPARTMENT WITHOUT REQUIRING SOPHISTICATED COMPUTER SKILLS FROM THE USERS

- INSTALL A DEDICATED MINI-COMPUTER IN YOUR INDUSTRIAL ENGINEERING DEPARTMENT FOR DIRECT ON-LINE ACCESS AND INTERFACE THE OUTPUT OF COMPLETE TIME STANDARDS WITH EXISTING SOFTWARE PROGRAMS ON YOUR MAIN FRAME COMPUTER

- UTILIZE A VARIETY OF ADDITIONAL PROGRAM FEATURES THAT WILL ADVANCE YOUR INDUSTRIAL ENGINEERING AND IMPROVE YOUR OVERALL PRODUCTION PLANNING AND CONTROL

APPENDIX A: REAPS TECHNICAL SYMPOSIUM AGENDA

TUESDAY, OCTOBER 14

1:00 -3:30 REGISTRATION — FOYER

9:00 GENERAL SESSION — WICKES
SESSION CHAIRMAN: E. L. Peterson, Peterson Builders

WELCOME
Spencer French, Sun Shipbuilding and Dry Dock Co.

SHIP PRODUCTION COMMITTEE PANEL OVERVIEWS:
SP-1- Facilities and Environmental Effects
R. Price, Avondale Shipyards Inc.
SP-2 - Outfitting and Production Aids
L D. Chirlllo, Todd Pacific ShipYards Corp.
o-23-1 - Surface Preparation and Coatings
J. Pcart, Avondale Shipyards Inc.

10:30 INFORMAL DISCUSSION PERIOD

GENERAL SESSION — WICKES
SESSION CHAIRMAN: G. H. Peck, Bath Iron Works

SPC PANEL OVERVIEWS (contd.)
SP7 - Welding
J. Fallick. Sun Shipbuilding and Dry Dock Co.

A PROGRESS REPORT ON THE REAPS PROGRAM
D. J. Martin. IIT Research Institute

12:00 LUNCH

1:30 GENERAL SESSION — WICKES
SESSION CHAIRMAN: J. R. Vander Schnaf, IITRI

SPC PANEL OVERVIEWS (contd.)
Introduction - Shlp Producibility Research Program
J. C. Mason. Bath Iron Works Corp.
SP.6 - The National Shipbuilding Standards Program
S. Walkow-FMb Iron Works Corp.
SP-8 - The Shipbuildlng Industrial Engineering Program
J. R. Fortin, Bath Iron Works Corp.

A COMPUTERIZED SOURCE FOR INFORMATION ON SHIPBUILDING AND DESIGN
D. G. Mellor, Maritime Research Information Service, National Research Council

A REPORT ON THE IPAD NATIONAL CONFERENCE
D. J. Martin. IIT Research Institute

3:00 INFORMAL DISCUSSION PERIOD

3:30 GENERAL SESSION — WICKES
SESSION CHAIRMAN: J. C. Mason, Bath Iron Works

FITNESS FOR PURPOSE: A NEW LOOK AT WELD DEFECT CRITERIA
L. W. Sandor, Sun Shipbuilding and Dry Dock Co.

CONSTRUCTION TOLERANCE STANDARDS
T. Krehnbrink, Sun Shipbuilding and Dry Dock Co.

THE IPD SYSTEM FOR INTERACTIVE PART CODING AND NESTING
R. C. Moore. Newport News Shipbuilding and Dry Dock co.

5:15 -6:30 RECEPTION — BARRY
Sponsored by IIT Research Institute

WEDNESDAY, OCTOBER 15

8:00 -3:30 REGISTRATION — FOYER

8:30 Concurrent Sessions

SESSION 1 — WICKES
SESSION CHAIRMAN: D. Spanninga, National Steel Shipbuilding

SHIPYARD PLANNING WITH THE COMPUTER: FACT OR FANTASY
S. Knapp. SPAR Associates, Inc

SHIPBUILDING PRODUCTION CAPACITY PLANNING
R. Frankel, MIT

THE OUTFIT PLANNING PROBLEM
R J. Graves, University of Massachusetts, and L. F. McGinnis, Jr., Georgia Institute of Technology

SESSION 2 — BARRY
SESSION CHAIRMAN: R. C. Moore, Newport News Shipbuilding

INTERACTIVE PRODUCT MODEL DEFINITION AND PART GENERATION SYSTEM
R. DiLuca, ltalcantieri S.p.A

DRAWING OFFICE TO PART CUTTING WITH A MINI-BASED ONLINE SYSTEM
W. Clark, Port Weller Dry Docks

STEERBEAR 3 WITH INTERACTIVE GRAPHICS
K. Holmgren. Kokums Computer Systems AB

10:00 INFORMAL DISCUSSION PERIOD

10:30 **Concurrent Sessions**

SESSION 1 — WICKES

SESSION CHAIRMAN: L. F. Liddle. Sun Shipbuilding

ECONOMICS OF COMPUTERS IN SHIPYARD PRODUCTION CONTROL
J. R. McReynolds and J. A. Burbank, Corporate Tech Planning Inc.

APPLICATION OF MODULAR SOFTWARE TO ESTABLISH "CLOSED LOOP" SYSTEM FOR SHIPYARD PRODUCTION CONTROL
H. S. Burgess, Arthur Andersen *& Co.*

PHOTOGRAMMETRIC THREE-DIMENSIONAL DIGITIZING OF PIPING ARRANGEMENT SCALE MODELS FOR COMPUTER INPUT
J. F. Kenetick, JFK Photogrammetric consultants, Inc.

SESSION 2 — BARRY

SESSION CHAIRMAN: P. M. Cafoni, General Dynamics Corp.

GENERATING NEW SHIP LINES FROM A PARENT HULL USING SECTION AREA CURVE VARIATION
R. McNaull, Maritime Administration

A NEW APPROACH TO FABRICATION DRAWINGS
D. P. Ross, CaIi & Associates, Inc.

EVALUATION OF ALTERNATIVE GENERIC COATINGS IN DIFFERENT SHIP AREAS
B. Fultz, Offshore Power Systems

12:00 LUNCH

1:30 GENERAL SESSION — WICKES

SESSION CHAIRMAN: J. C. Mason, Bath Iron Works

IMPROVING SHIPBUILDING PRODUCTIVITY THROUGH INDUSTRIAL ENGINEERING
R. P. Lutz. University of Texas

AN OVERVIEW OF THE MANUAL AND THE COMPUTERIZED "MOST" WORK MEASUREMENT SYSTEMS
W. Yates, H. B.Maynard & Co., Inc.

3:oo INFORMAL DISCUSSION PERIOD

3:30 GENERAL SESSION — WICKES

SESSION CHAIRMAN: F. San Miguel. J. Ray McDermott Co.

QC CIRCLES FOR IMPROVING QUALITY AND PRODUCTIVITY
C. P. Alexander. Ann Arbor Consulting Associates, Inc.

THURSDAY, OCTOBER 16

8:00-10:30 REGISTRATION — FOYER

8:30 **Concurrent Sessions**

SESSION 1 — WICKES

SESSION CHAIRMAN: 0. Gatlin, Avondale Shipyards

NEW APPLICATIONS OF INDUSTRIAL ROBOTS IN SHIPBUILDING
J. W. Hill. SRI International

THE AVONDALE PIPE SHOP: PREPARING FOR PRODUCTION
H. F. Arnold, Avondale Shipyards, Inc.

AUTOMATED HANDLING FOR FLAME CUTTING
J. Seelinger. Anderson Engineers, Inc.

SESSION 2 — BARRY

SESSION CHAIRMAN: B. G. Bohl. Bethlehem Steel Shipbuilding

DEVELOPMENT OF EFFECTIVE COMPUTER CAPABILITIES FOR A DESIGN AGENT
W. B. Fritz, J. J. Henry Co., Inc.

COMPUTER SHARING BY SHIPBUILDERS AND DESIGNERS
F. Cali, Cali & Associates, Inc.

USE OF AUTOKON DESIGN FACILITIES - A DESIGNER'S PRESENTATION OF ***AN*** ACTUAL CASE
H. Oeigarden, Shipping Research Services A/S

10:00 INFORMAL DISCUSSION PERIOD

10:30 GENERAL SESSION — WICKES

SESSION CHAIRMAN: L. D. Chirlllo, Todd Pacific Shipyards

JAPANESE TECHNOLOGY THAT COULD IMPROVE U. S. SHIPBUILDING PRODUCTIVITY
J. R. Vander Schaaf, IIT Research Institute

IMPLEMENTING IHI TECHNOLOGY AT AVONDALE
C. J. Starkenburg, Avondale Shipyards, Inc.

11:30 ADJOURNMENT

12:00-3:45 TOUR — TOURS-SUN SHIPBUILDING AND DRY DOCK CO.

1:45-5:30 TOUR 2

APPENDIX B: REAPS TECHNICAL SYMPOSIUM ATTENDANCE LIST

Philadelphia, Pennsylvania

OCTOBER 14-16, 1980

A&P APPLEDORE LTD.
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England

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Director

P.A.C. Slee

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Sales Engineer

M. C. Daley
Manager, Public Relations & Advertising

Peter D. Stoupas
Sales Manager

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Systems Analyst

Otto P. Jons
Vice President Engineering

Joseph Rudnicki
Sr. Naval Architect

ADVANCED TECHNOLOGY, INC.
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John k. Knobel
Program Director

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Bruno Nadalin
Assistant Chief Surveyor

AMERICAN SHIPBUILDING Co.
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Jerry D. Buzza
Corporate Director, Management Info. Systems

Ray Francis
Technical Manager

Gavin Sproul
VP Engineering

ANDERSON ENGINEERS, INC.
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John A. Seelinger
Vice President Sales

W. Mason Smith
Vice President Marketing

ANN ARBOR CONSULTING ASSOCIATES, INC.
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Ann Arbor, MI 48103

C. Philip Alexander
President

ARTHUR ANDERSEN & co.
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Henry S. Burgess
Manager

AVONDALE SHIPYARDS, INC.
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New Orleans, LA 70150

Harris F. Arnold
VP, Data Processing

0. Gatlin
Manager of Plant Engineering

John Peart
MARAD Program Manager

Dick Price
Project Mgr. SP-1 Panel

Charles J. Starkenburg
VP, Production Planning and Scheduling

Michael B. Wilson
Manager Production Systems Control

BATH IRON WORKS
700 Washington Street
Bath, ME 04530

Steven G. Buttner
Program Manager

Joseph R. Fortin
Project Engineer

Peter E. Jacquith
Mgr. Production Planning and Control

John C. Mason
MARAD Program Manager

George Peck
Systems Analyst

Richard B. Siek

Samuel Wolkow
Project Engineer

BAY SHIPBUILDING
605 N. 3rd Ave
Sturgeon Bay, WI 54236

John Schauske
AUTOKON Coordinator

BETHLEHEM CORP.
Shipbuilding-Central Technical Div.
Sparrows Point, MD 21219

Vernon G. Adams
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Bruce G. Bohl
Sr. Programmer/Analyst

James P. Kozo
Project Manager

David T. Vermette
Planner

BETHLEHEM CORP.
Shipbuilding, Facility Services
Martin Tower
Bethlehem, PA 18016

H. A. Baierlein
Superintendent, Maintenance Practices

Herbert I. Freinberg
General Manager, Operations and Facilities

T. Hartmann-Hansen
Superintendent, Facility Planning

BETHLEHEM STEEL CORP.
Shipbuilding Facility Services
Martin Tower
Bethlehem, PA 18016

John J. Heffernan
Contract Manager

Rockwell Holman
Manager-Production

Wendell O. Robertson
Supt. of Mgmt. Dev.

John G. Rogers
Manager-Facilities

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Senior Shipyard Engineer

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Research & Development Manager

G. R. Snaith
Director of Research

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Rene P. Richard
SSC Director, Canadian Patrol Frigate Program

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Charleston, SC

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P. M. Dill
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D. B. Greason
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Wade Palmer

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Alan Telfer
Chief Planner - Engineering

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John Wallent
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Engineering Specialist

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B. J. Breen
Manager, CAD/CAM

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Margarita Hernandez
REAPS Librarian

Douglas J. Martin
REAPS Program Manager

James R. VanderSchaaf
Sr. Naval Architect

Richard B. Wise
Chairman, REAPS Technical Symposium

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Jeanne Miller
Asst. to President

Marvin B. Miller
President

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Specialist Design

Vincent R. Ruta
Designer Specialist

Richard V. Shields
Manager, Technical Applications

F. D. Welch
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Deputy Senior Manager, IHI International

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John F. Kenefick
President

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Gerald Bilbo
Production Engineer

Curtis Halliburton
Mold Loft Manager

Clyde B. LaRue
Director, Production Control

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Thomas D. Kuhlmeier
Supt. Lofting and Plate Burning

Otis Edwards
Prop. Mgr.

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Andre Taschereau
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James G. Wilson
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Manager, Shipbuilding Research Program
Code M920-Room 4610

John M. Hotaling
Manager Shipbuilding Analysis

Freddie T. Johnson
Chief Engineering
Office of Ship Construction

Edward S. Karlson
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Office of Ship Construction

Joseph Kim, Code M724.3
Div. of Naval Architecture

Alexander C. Landsburg
Manager, Computer Aided Cost Analysis
Room 4868

Zelvin Levine
Director, Office of Advanced Ship Development
Code 920

Robert F. McGinn
Shipbuilding Analyst, Code M-723

Robert McNaull
Computer Specialist
Room 1600

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Carl Setterstrohm
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Div of Naval Architecture

Robert Schaffran
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APPENDIX C: SHIP PRODUCTION COMMITTEE CHAIRMEN

The current chairmen of the various panels within the Ship Production Committee (SPC) are identified below.

The SPC chairman is:	Mr. Ellsworth L. Peterson President Peterson Builders, Inc. 101 Pennsylvania Street Sturgeon Bay, Wisconsin 54235	414/743-5577

Requests for additional information concerning the various SPC SNAME Panels should be directed to the panel chairman listed:

Panel SP-1: Facilities Panel SP-3: Environmental Effects	Mr. Ollie H. Gatlin Vice President, Facilities Avondale Shipyards, Inc. P.O. Box 50280 New Orleans, Louisiana 70150	504/436-5171
Panel SP-2: Outfitting and Production Aids	Mr. Louis D. Chirillo R&D Program Manager Todd Pacific Shipyards Corporation Seattle Division 1801 16th Avenue, S.W. Seattle, Washington 98124	206/623-1635 x496
Panel SP-6: Standards Panel SP-8: Industrial Engineering	Mr. John C. Mason MarAd Program Manager Bath Iron Works Corporation 700 Washington Street Bath, Maine 04530	207/443-3311 x2146
Panel SP-7: Welding	Mr. John C. Fallick MarAd Program Manager Sun Shipbuilding, Inc. Chester, Pennsylvania 19013	215/876-9121
Task Group 0-23-1: Surface Preparation and Coatings	Mr. John Peart MarAd Program Manager Avondale Shipyards, Inc. P.O. Box 50280 New Orleans, Louisiana 70150	504/436-5314
The REAPS Group:	Mr. Douglas J. Martin Program Manager IIT Research Institute 10 West 35th Street Chicago, Illinois 60616	312/567-4618

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